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INVESTIGATION OF INSIDE LIGHT REFLECTION PROBLEM ON THE FLAT PL--ETC(U)

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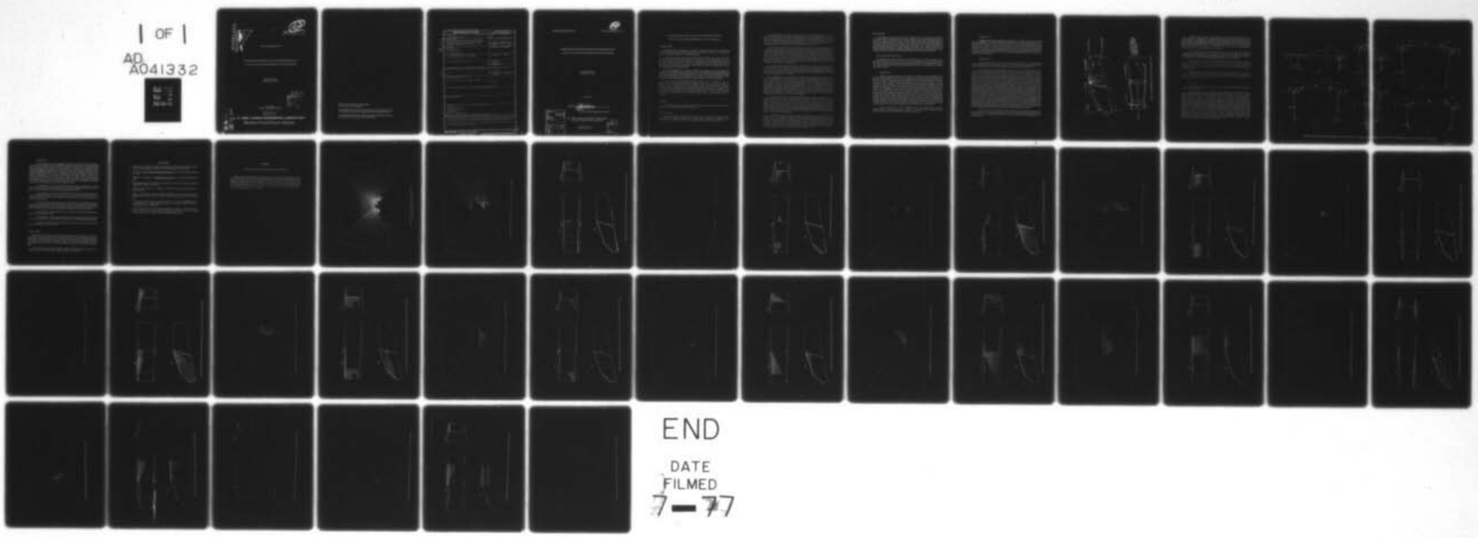

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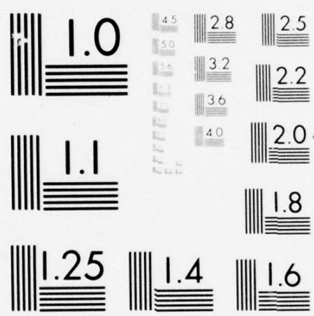
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Technical Memorandum 13-77

INVESTIGATION OF INSIDE LIGHT REFLECTION PROBLEM ON THE FLAT PLATE CANOPY (FPC) FOR MODEL 209 AH-IS HELICOPTER

Harry R. Stowell
Christopher C. Smyth

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Various approaches were examined for a possible solution to the light-reflection problem inside the Model 209 AH-IS helicopter cockpit with the flat-plate canopy (FPC). A computer program was developed to identify primary light reflections inside the FPC at the pilot's eye position.

Modifying the side panels on the FPC with curved surfaces may be the only satisfactory solution to the inside light-reflection problem.

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APPROVED: John D. Weisz
JOHN D. WEISZ
Director
U. S. Army Human Engineering Laboratory

U. S. ARMY HUMAN ENGINEERING LABORATORY
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INTRODUCTION

A study was done to investigate the problem of inside light reflections on the flat-plate canopy (FPC) and to find a solution to the problem. The FPC was adopted for the Model 209 AH-IS helicopter for the purpose of reducing solar glint.

In night operations, flying nap-of-the-earth (NOE), the FPC creates mirror-type light reflections inside the cockpit at the pilot's eye. Reflected light causes specular glare in the visual field that impairs the pilot's vision outside the cockpit and can cause problems associated with pilot disorientation. The pilot is not able to discriminate between the light reflection and the light source on the ground. This problem creates a hazard to the safety of flight and is likely to have a serious impact on external vision.

The FPC was designed for the AH-IQ helicopter and adopted for the Model 209 AH-IS helicopter in an effort to reduce solar glint, which in turn would reduce the susceptibility of aircraft to visual detection. The FPC improved the solar-glint problem, while creating a problem with inside light reflection from light sources on the ground in night operations (7). Light reflections on surfaces inside the cockpit are a problem with use of night-vision devices (1).

The US Army Human Engineering Laboratory (USAHEL) was requested by the Air Mobility Research Development Laboratory (AMRDL) to do a study on the FPC light-reflection problem and try to find a solution. Time constraints limited the experimentation needed to validate the analysis. Estimates were made based on analysis of light reflection inside the FPC. Results indicate a satisfactory solution to the inside light-reflection problem on the FPC may not be possible unless the side panels are modified from a flat surface to a curved surface. The FPC must provide both the pilot and the copilot adequate vision to perform NOE safely and efficiently.

METHOD

Two methods were used to identify the light-reflection problems with FPC. They were computer analysis and manual analysis of critical rays.

Computer Analysis

A computer program was developed to identify the primary light reflections inside the FPC at the pilot's eye position. Analysis of the computer data was useful in considering various approaches which could lead to a solution of the inside reflection problem with the FPC.

A three-dimensional ray-tracing program was written to trace straight-line rays from the position (nominal) of the pilot's eye to reflecting points on the internal surfaces of the canopy. Each ray is traced between reflecting surface points until a non-transparent surface is reached. The reflectance and directional cosines of the external ray and reflected ray are computed. In this way, a reflected ray is traced backwards from the pilot's eye to all possible external sources. The program uses standard techniques of vector geometry and optics (1, 4).

The program is applicable to any canopy design, although application is limited to the FPC in this report. The canopy is specified as a covering net of flat surfaces, each described by the coordinates in three-dimensional space of the vertices and the rotational order in which they are listed. The program computes the intersection point of a straight-line ray given its directional cosines and origin point with a plane containing each surface segment in turn. The reflection point is that interception point which is contained within the edges of the corresponding segment. The angle of incidence is computed for this point along with the reflectance value and the directional cosines for the transmitted and reflected rays. The reflected ray then becomes the incident ray for the next set of computations.

The program includes obstructing surfaces such as the pilot's control panel and side armor panels and also the seat, side armor and gunner's sight for the copilot. These are specified in the same manner as the canopy segments with, however, appropriate coding added. The computation of a reflection point for a ray or such an obstructing surface renders the computation complete since the ray is considered to be absorbed.

This computation process was repeated for various pilot-viewing directions indexed over a quarter sector bounded by vision directly to the front, to the side and top and bottom. In this way, a table can be constructed listing all possible internal reflection points and the corresponding external light orientations and surface entry positions. This approach generated a large amount of data (i.e., approximately 60,000 lines for a $1^{\circ} \times 1^{\circ}$ viewing angle increment). Consequently, a computer graphics program was written to show the incident ray entry points and corresponding primary reflection points as seen from side, top and front views of the FPC, and on also a perspective drawing seen from the pilot's position. Standard computer graphics techniques were used (7). The results of this analysis are shown by the FPC in Appendix A containing hard-copy figures of the CRT graphics displays.

The above-mentioned figures show the relationship between incident entrance points on one canopy surface and the primary reflection points on another surface as seen at the pilot's position. These figures show possible relationships between external sources and internal (primary) reflections. The data points could just as well have been separated by external light incident angles and internal reflections. Also possible is a study based on realistic scenarios in which reflections could be shown for external source positions relative to the aircraft at suitable values of flight time. Time constraint precluded these developments during the research; however, the above-mentioned figures show the total reflections possible for an array of external light and, therefore, the full extent of the problem.

The program as developed is readily applicable to configurations other than the FPC. (See approach no. 5 in discussions of solutions for an application to a simple curved canopy.) The program could just as readily be applied to other curved configurations simple or complex. Programs were started to also (1) compute and display "glint" for various configurations, and (2) "optimally" design canopy configurations by numerical methods. These programs are available for future assistance by HEL to other agencies as needed. Information on programming is available from HEL and will be released in technical memorandum form.

Manual Analysis

Critical light rays were traced manually on candidate canopy configurations to determine the relative effects of sunlight glint for daytime operations and ground light glare inside the cockpit for night operations. The results of these glare and glint analysis are discussed below under each approach considered. Analysis of the inside light-reflection problem indicated rays from light sources on the ground caused primary reflections on all canopy side panels and overhead panels depending on the light incident on the surface. Solar reflections can also be a problem in daytime at certain sun angles. Specular reflection from the sun interferes with outside viewing and the pilot's ability to see targets is impaired by reflections in the visual field.

Glint/Glare Reduction Approaches

Various approaches were considered for a possible solution to the inside reflection problem with the FPC. There was some merit in each of the various approaches, even though some may have appeared initially unacceptable from the human factors aspect. In each approach an attempt was made to identify the problem associated with the pilot's visual performance in reducing inside light reflections.

Approach No. 1

Reflection-reducing coating such as HEA (5) conforming to MIL-C-14806 (4) and AMS-2521 (4) deposited on the surface of cover glass for instruments has been widely used in the aircraft industry for both military and commercial aviation. Research is being done to develop a method to deposit reflection-reducing coating on plastic transparent surfaces. To date, information is not available on whether improvements were made to deposit reflection-reducing coating on plastic transparent surface that can meet environmental requirements. In this approach, the assumption is that a suitable method of applying reflection-reducing coating on plastics may be possible. Tests have shown reflection-reducing coating deposited on glass surfaces reduce the amount of light reflected from a value of 5 percent or 10 percent to less than 1 percent with corresponding gain in light transmission (8). This is not to be confused with various tinting processes used to reduce brightness from outside. Tinting a transparent surface is generally associated with serious light-transmission losses and does not help solve the light-reflection problem. Reflection-reducing coating applied to canopy surfaces will improve visibility over uncoated canopies and will reduce the amount of light reflected inside the cockpit. Even though the light reflection is not eliminated completely, it is reduced to a level that will permit the pilot to discriminate between the light reflection and the actual light source on the ground.

Tests will need to be done to determine the exact improvements using the reflection-reducing coating deposited on canopies for aircraft. Reflection-reducing coating applied to canopy surfaces should enhance any design configuration.

Approach No. 2

Adjustable visors and curtains were considered as a possible solution to the inside reflection problem with the FPC. Different shapes and sizes of visors along with the use of curtains which could be extended in night operations were considered for blocking the inside light reflected at the pilot's eye position. It was determined that to effectively block the primary reflections at the pilot's eye, the visual field would be so obstructed by these devices, pilots could not fly by visual reference outside. Adjustment on these devices, during flight, would be nearly impossible while operating the controls. This approach was abandoned because it created more problems than it would solve.

Approach No. 3

Opaque louvers (vanes) or slats on inside surfaces of the FPC were considered along with opaque fences mounted external to improve the inside light-reflection problem. Devices considered in Approach No. 2 were also considered for possible application (Figure 1).

The main concern was reducing light reflection for the pilot. The pilot has primary responsibility of flying the helicopter and should, therefore, be assigned a higher priority than the copilot on the visual field. However, the copilot is responsible for the navigation task on the mission and must have sufficient uninterrupted visual field to perform his duties as navigator. Using a mock-up cockpit of the Cobra with the FPC, observations in the front cockpit confirmed light rays from a single light source on the ground produced as many as five separate light reflections at the eye position. Some secondary light reflections were observed to be nearly as bright as the primary light reflection. The same light-reflection problem prevailed in the pilot's position. The pilot sees some of the light reflected on the FPC surfaces in the copilot station. The side panels cause the most serious light-reflection problem for both pilots. Some light reflections causing a problem at the pilot's eye are visible on the sloping front panel. Louvers (vanes) may be used on the pilot's side panels to reduce the amount of reflected light. However, some loss in the visual field through the side panels will be experienced by the pilot viewing with louvers. The extent of occlusion caused by the louvers can be minimized by aligning each louver (vane) relative to the pilot's eye position. The visual field may be reduced as much as 20 percent with louvers. The thickness of louvers will be the largest contributor to the loss in visual field. Louvers will appear as bars to the pilot using binocular vision. However, by moving his head slightly, the pilot may look at a particular point between the louvers. The louvers should extend from the forward edge of the pilot side panels to a point back of the pilot's head. At a point approaching the 90° side-viewing angle, the louvers should not be angled directly with the pilot's eye or else external lights will reflect between louvers inside the FPC at the pilot's eye position.

The use of the louvers (vanes) on the copilot's side panels would create a serious viewing problem to the copilot and would reduce the pilot's visual field forward by 50 percent or more. Louvers were not considered a satisfactory solution to the light-reflection problem on the front side panels.

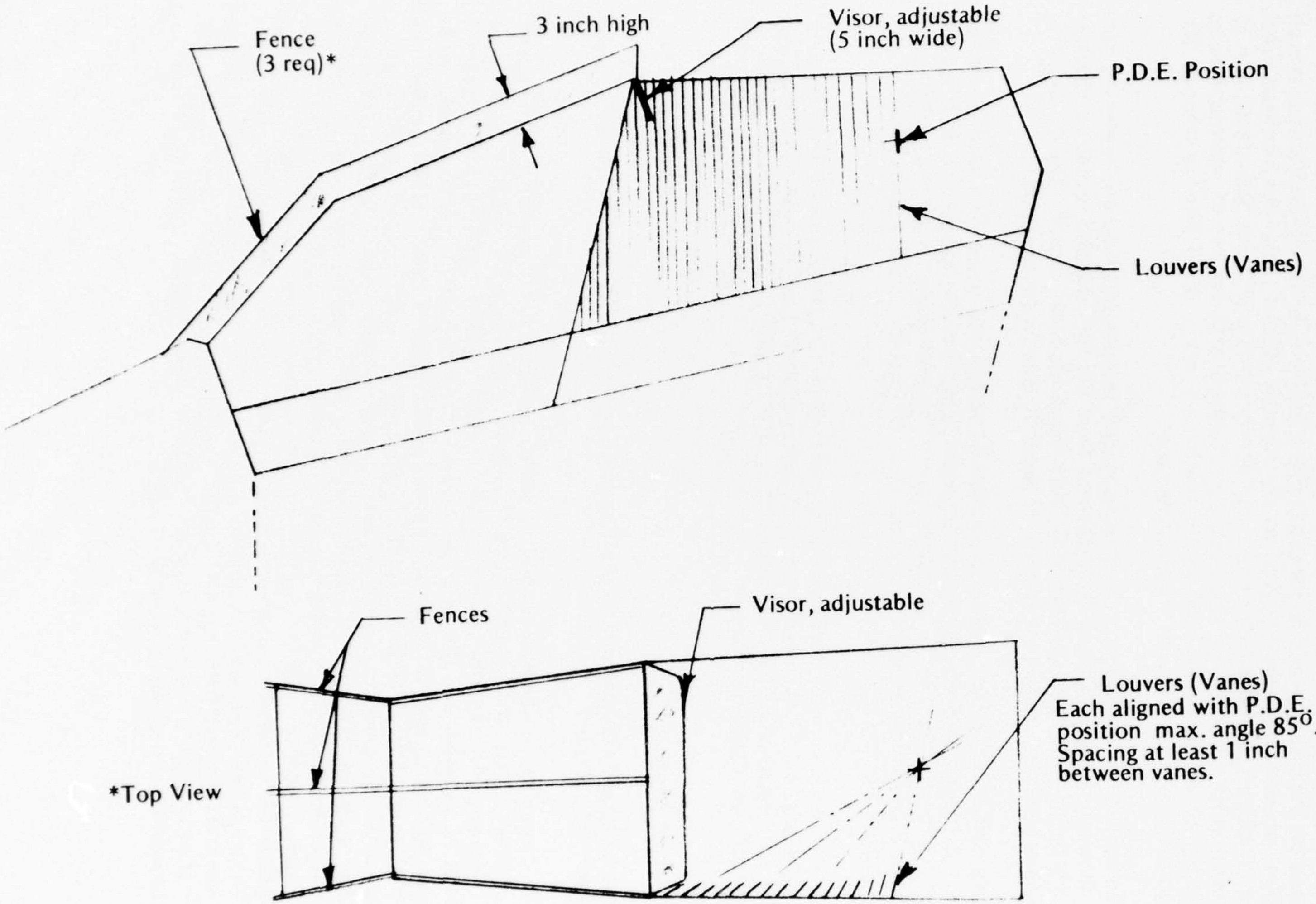


Figure 1. Model 209 AH-IS helicopter with flat-plate canopy.

However, opaque external fences (Figure 2) can be installed externally on the windscreen and on the sloping front overhead panel to effectively reduce light reflections at each pilot's position. An adjustable visor located on the forward edge of the pilot's overhead panel may be used to block light reflection on the sloping front overhead panel. Some occlusion to both pilot and copilot will occur in the visual field forward with the use of external fences. However, occlusion in the copilot's visual field will only occur when viewing through the windowscreen and looking up through the overhead panel.

The addition of a pull-type opaque curtain over the copilot's head on the sloping front overhead panel mounted approximately mid-distance from the forward edge, would be effective in reducing 10 or 15 percent of the light reflection inside the front cockpit. The curtain will, however, create a loss in the visual field forward of about 20 percent for the pilot.

Light reflection in the pilot's position should be reduced about 70 percent using the fences, visor and louvers as described in this approach. This does not include a curtain on the sloping panel overhead. The loss in the pilot's visual field associated with this technique is estimated at 10 or 15 percent forward and about 20 or 30 percent to the sides from the pilot's design eye position.

Light reflection in the copilot's position should be reduced about 10 or 15 percent. Loss in the copilot's visual field is estimated at 5 percent forward and zero to the sides. Tests must be done to identify accurately the improvement on light reflection inside the FPC by using the procedure outlined in this approach.

Approach No. 4

This approach considered incorporating curve surfaces inside the FPC to reduce light reflections inside the cockpit.

The possibility of adding a secondary curved transparent curtain inside the FPC was considered. The secondary transparent curtain could be thin enough to operate on wind-up rollers and follow sets of tracks with predetermined curves. In daylight operation, the transparent curtains could be stowed on the pull-up rollers. The transparent curtain could have reflection-reducing coating applied. When the transparent surface became unserviceable because of abrasion from usage, the curtain could readily be replaced at a relatively low cost. The coating would enhance visual performance through the secondary surface and reduce the amount of light reflected. After doing analysis on light reflections using the transparent curtain with curved surfaces, it was determined to be unsatisfactory. The light incident on the FPC from external light source enters the cockpit and is reflected on inside surfaces of the FPC at about the same points as without the secondary transparent curtains. The refractions through the thin curve transparent surface is very small and the angle of the light rays changes very little. Light is also reflected on the inside curved transparent surface at a different angle than on the FPC, creating added light reflections of a lower magnitude. The transparent curtain, therefore, offers no solution to the light-reflections problem inside the FPC.

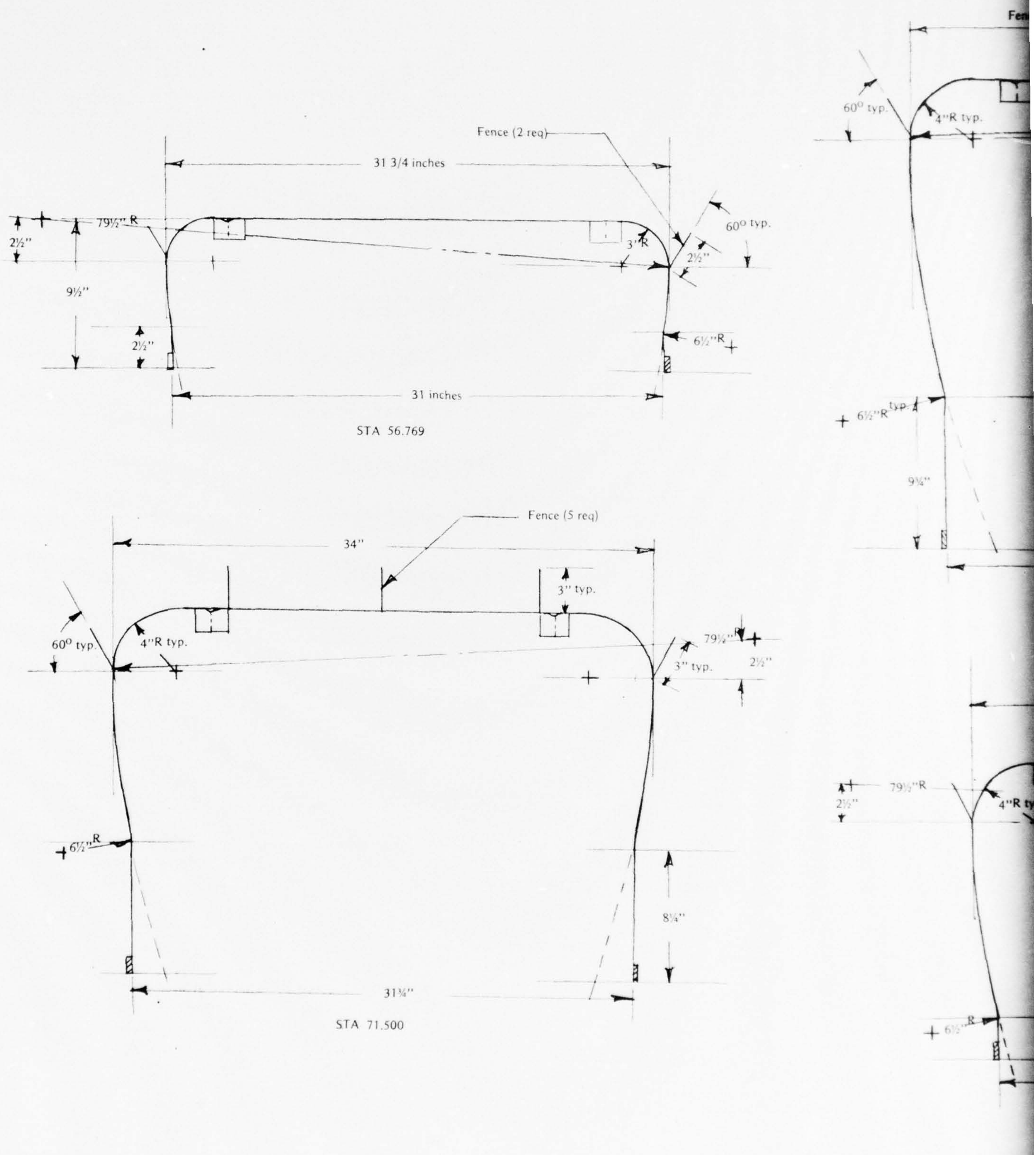
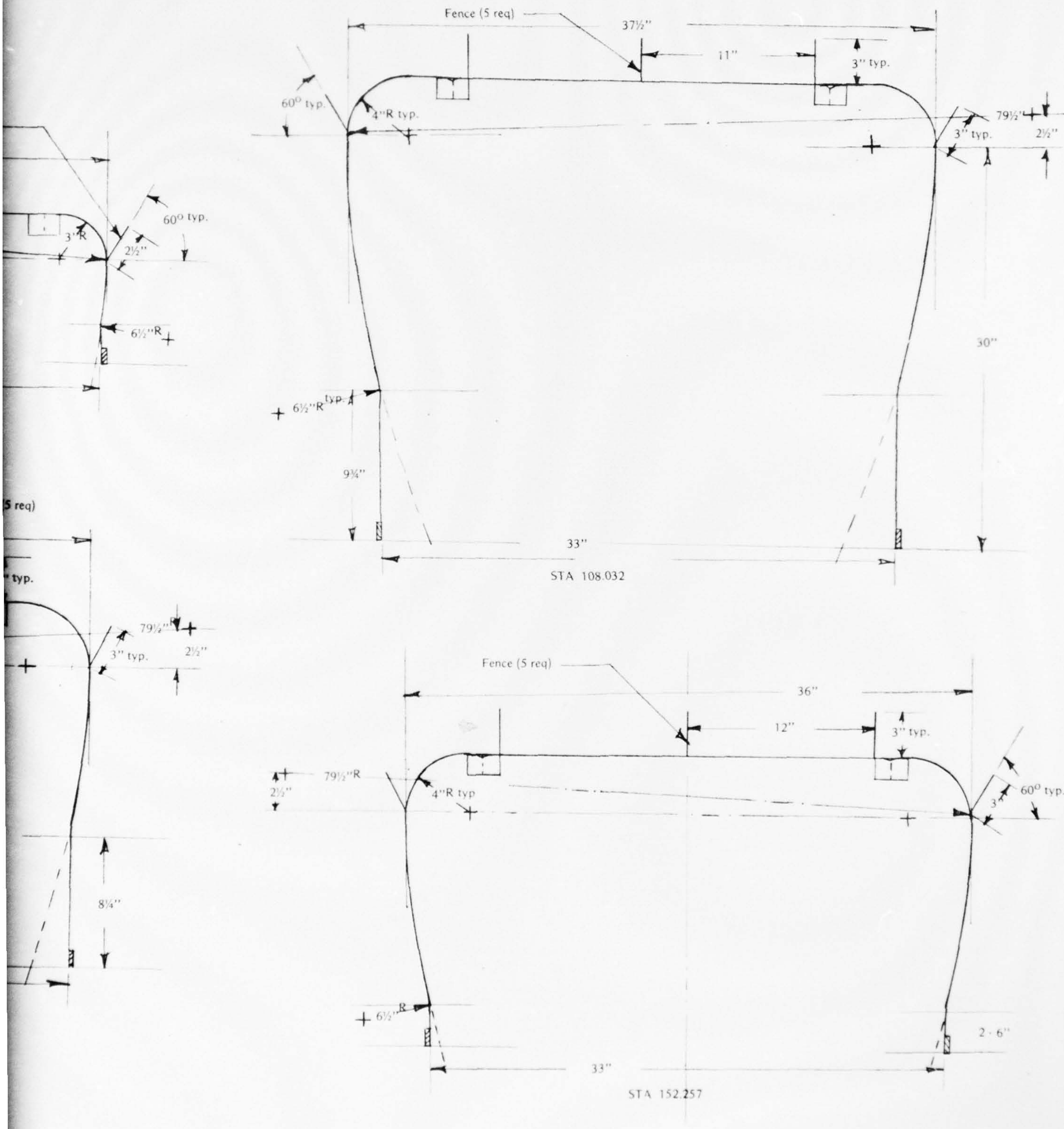


Figure 2. Proposed canopy shell design for the model AH–IS helicopter with



design for the model AH–IS helicopter with curved surface on side panels.

2

Approach No. 5

It was decided to look at the possibility of designing curved surfaces for the side panels on the FPC to be compatible with existing canopy frame structure. Both the solar glint problem and the inside reflection problem had to be considered in designing the curved side panels. Several test models of canopy sections were fabricated for evaluation. Figure 2 depicts the curved side panels designed for consideration. The surface is a simple curve designed to reduce solar glint and reduce inside reflections on a canopy configuration for the Model 209 AH-IS helicopter. Test sections incorporating the curve design were observed under bright sunlight conditions from morning to evening in order to look at the full range of sun angles. The curve configuration performed as well or better than a flat plate with vertical sides under solar light. When compared with the FPC, performance was better with curve surface because the inward slope of the side panels on the FPC caused glint at sun angles 15 degrees or more.

The inside light reflections were analyzed using computer data developed for the FPC, but computer graphics have not been applied to the results. Inside light reflections from external light sources were reduced by about 70 percent as compared to the FPC.

It was necessary to incorporate opaque fences on the top of the canopy, Figure 2, to prevent a solar glint problem from the upper curve sections of the canopy. The fences also serve to reduce inside light reflections from a bright sun and from lights of other aircraft such as in formations flying at night.

The canopy incorporating curved panels will increase the forward visual field by about 20 percent over the standard curved Cobra canopy. Also, the curved side panels provide better visibility downward than the FPC or the standard curved canopy because of the outward bow effect. The pilot is able to see about 5 degrees inward looking down from a vertical plane.

The curve surface on side panels will help to reduce flutter associated with helicopter vibrations experienced with the FPC.

The configuration incorporating the curved side panels should form a canopy shell that can readily be fitted to the existing canopy frame structure of the Model 209 AH-IS helicopter.

A model of the improved canopy configuration should be tested on a mock-up cockpit before a flying model is fabricated for test.

CONCLUSIONS

Based on the work done by HEL to look at various approaches for a possible solution to the inside light-reflections problem on the FPC Model 209 AH-IS, it appears only one solution is acceptable, considering the human factors aspect of the problem. That is a redesign of the FPC incorporating curved side panels described in Approach No. 5. This would produce a minimum inside light reflection in both day and night operations. This approach also produces less solar glint.

In addition, if reflection-reducing coating is applied to transparent plastic surfaces such as canopies, it would enhance any canopy configuration used for helicopters.

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APPENDIX

ENTRY POINTS AND PRIMARY-REFLECTION POINTS

Figure 1A shows all possible entry points which can generate primary reflections reaching the pilot's position. Figure 2A shows all possible primary reflection points. Both figures are in perspective as seen from the pilot's position of the canopy transparent surfaces. The following Figures 3A through 31A show a breakdown by surfaces of entry points on one surface and primary reflection points on another. The figures occur in pairs for each such surface relationship with the first figure being side, top and front views and the following figure a corresponding perspective for the pilot's nominal eye position.

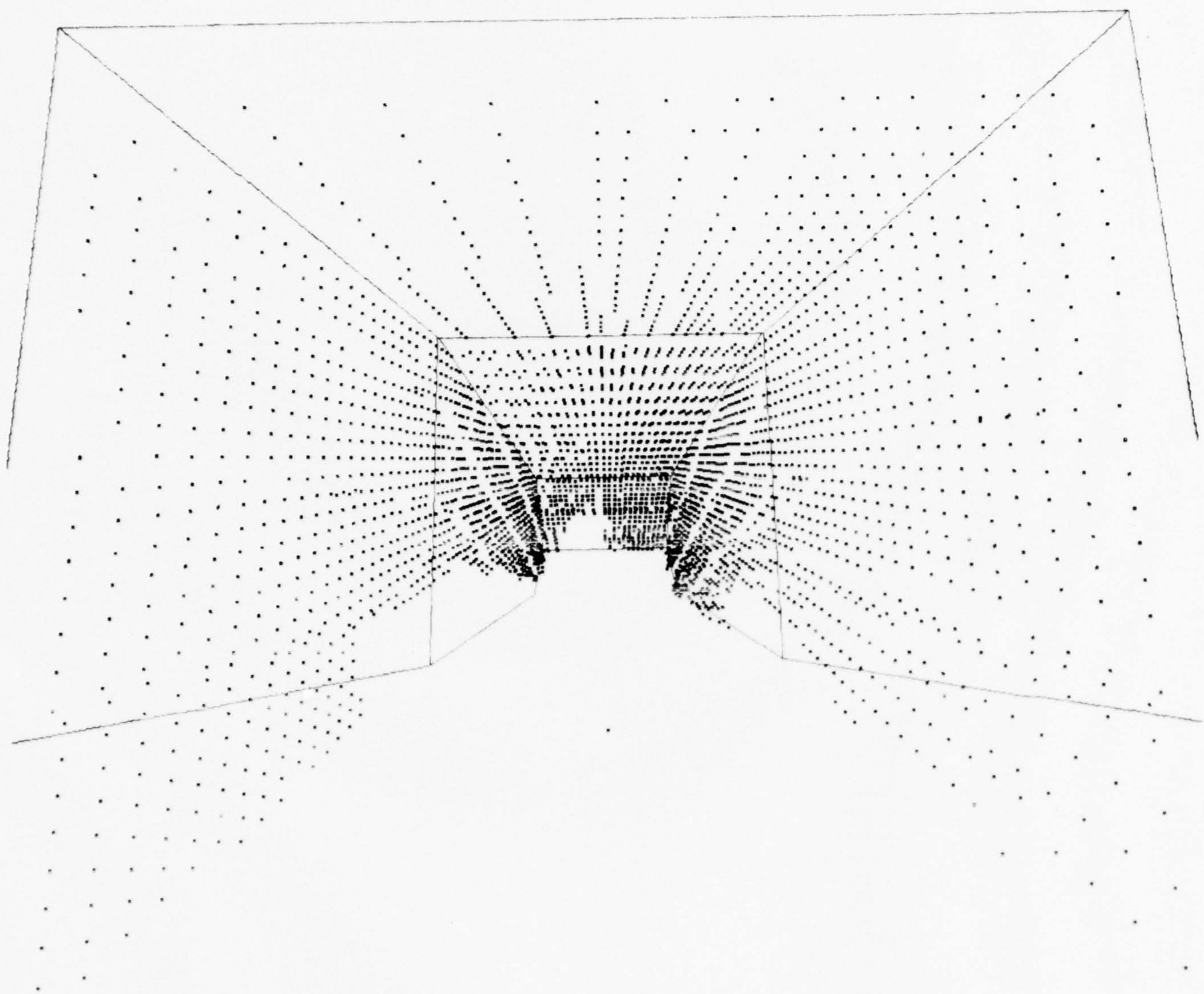

Figure 1A. Perspective view from pilot's position of all possible entry points for external light rays on right-hand side of FPC.

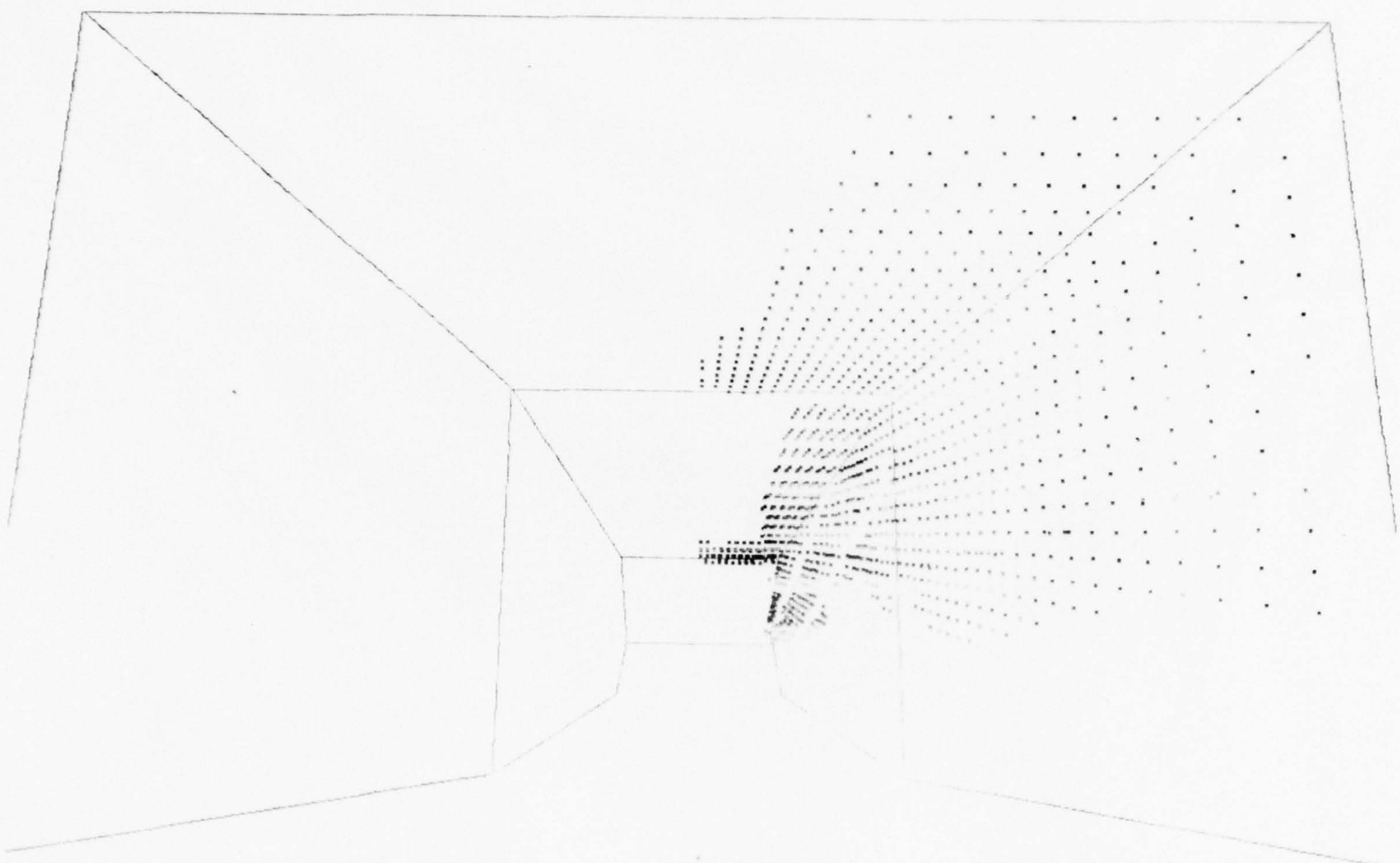

Figure 2A. Perspective view of all possible reflection points caused by light sources of Figure 1A.

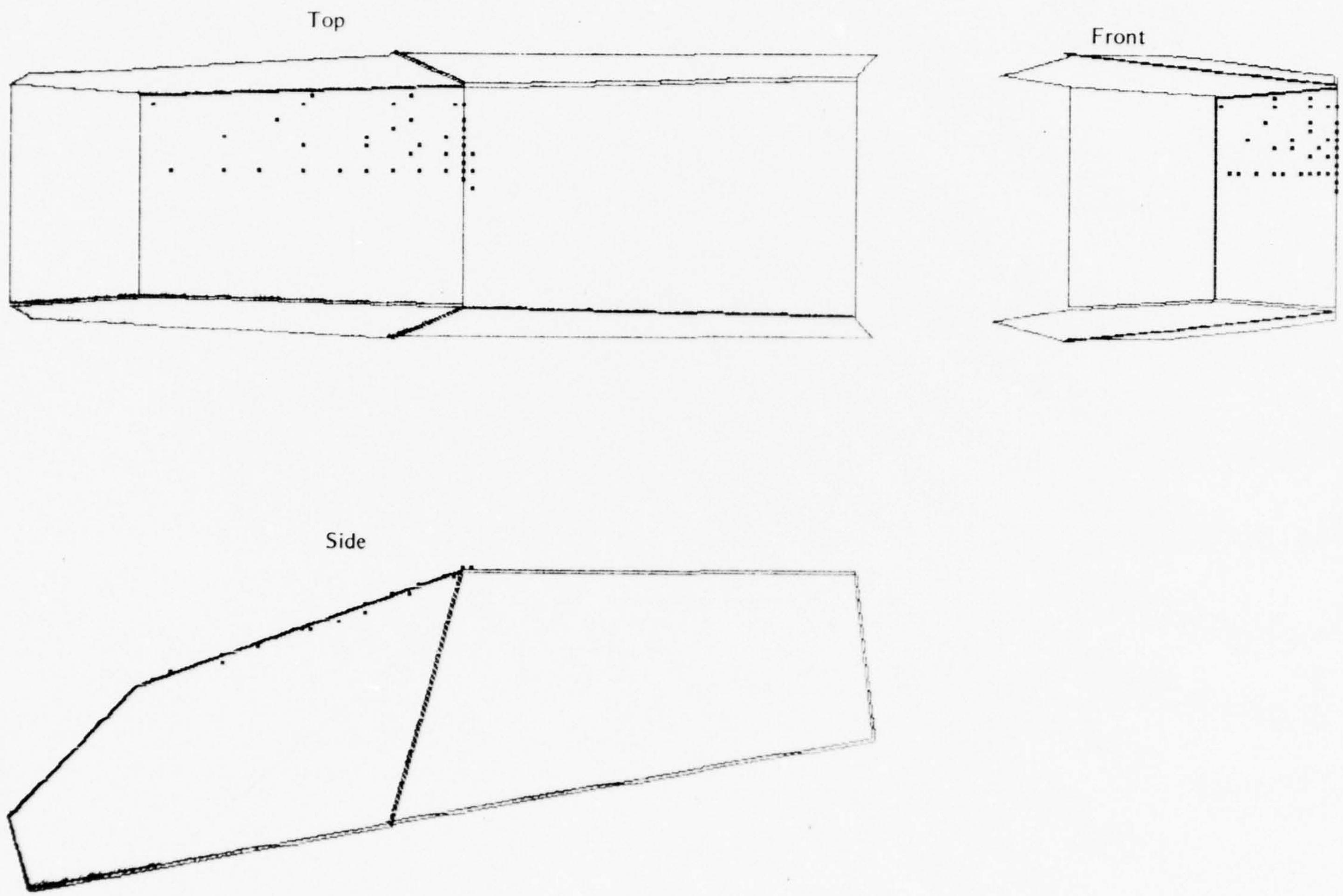

Figure 3A. Primary reflection points on top surface due to external light rays entering upper front surface.

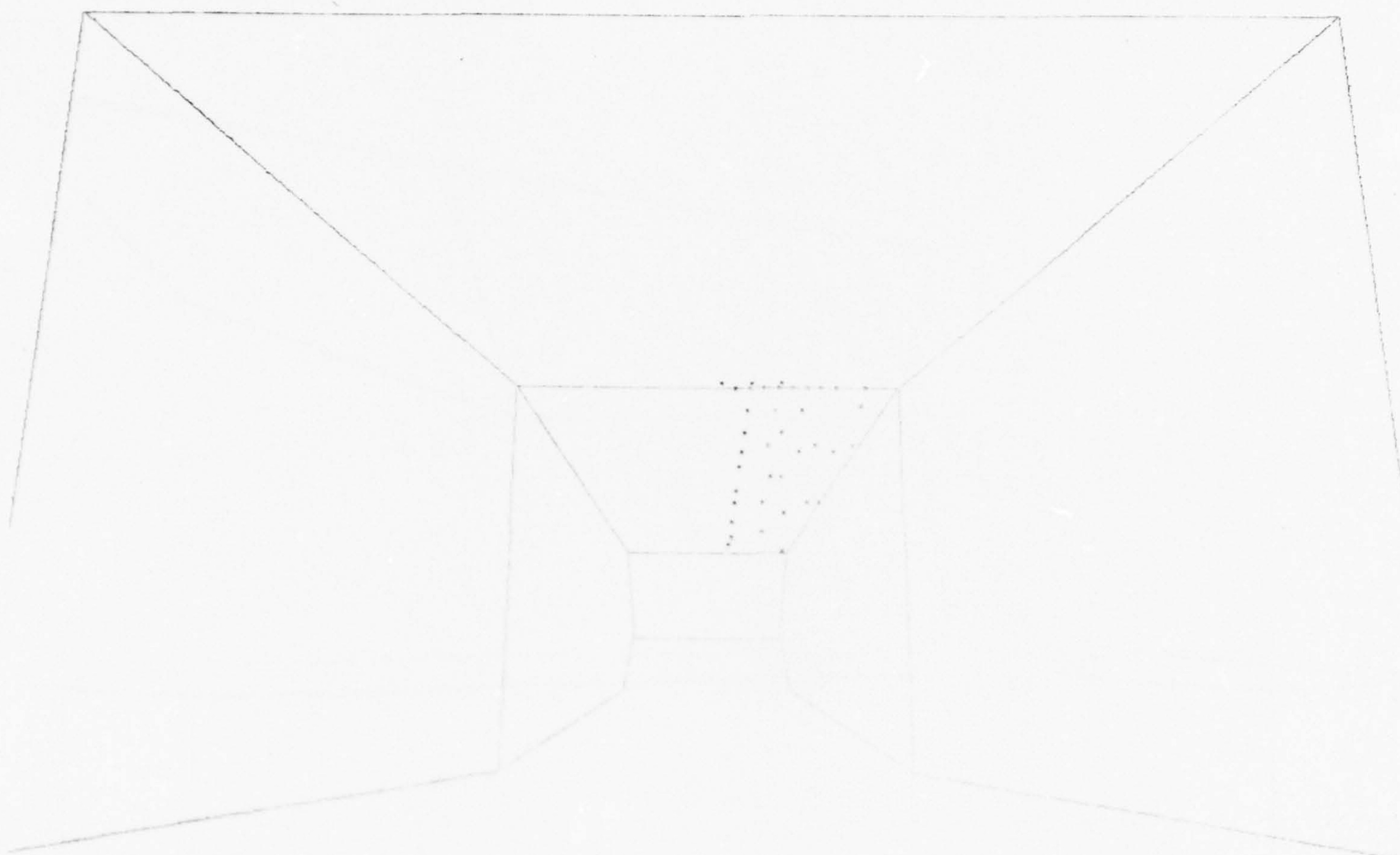

Figure 4A. Perspective reflection points on top surface due to external light rays entering upper front surface.

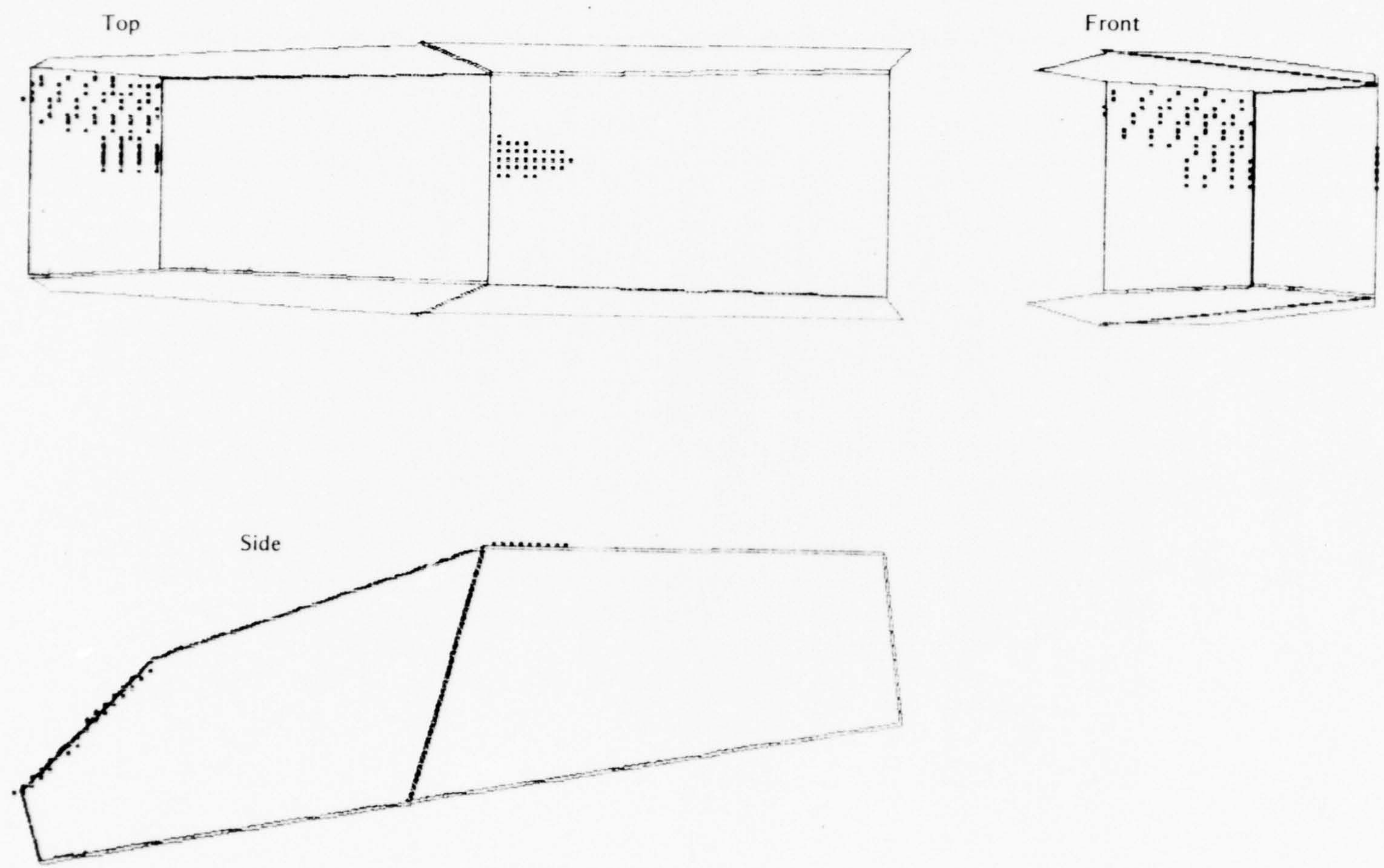

Figure 5A. Primary reflection points on top surface due to external light rays entering lower front.

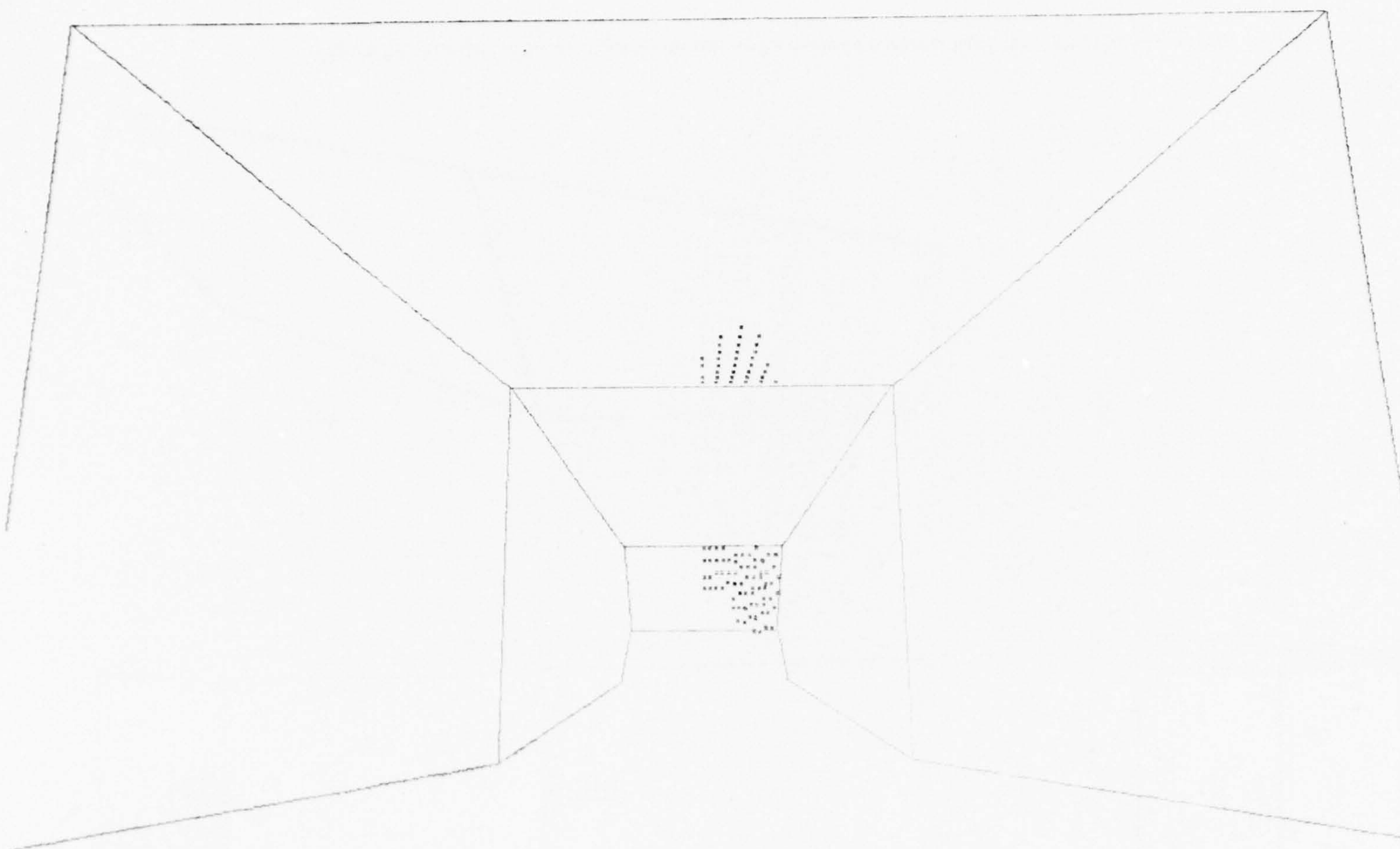

Figure 6A. Perspective reflection points on top surface due to external light rays entering lower front.

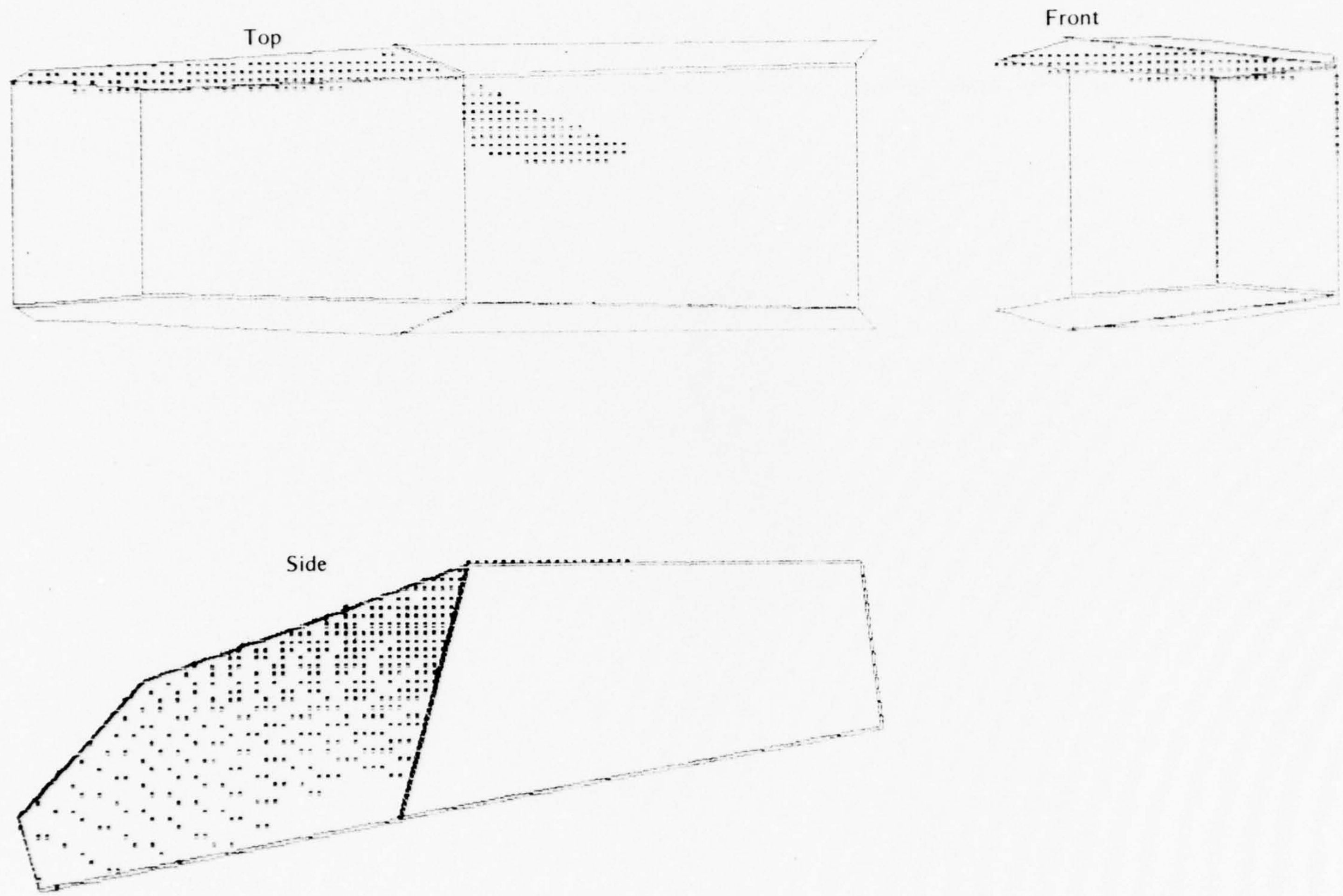

Figure 7A. Primary reflection points on top surface due to external light rays entering forward side.

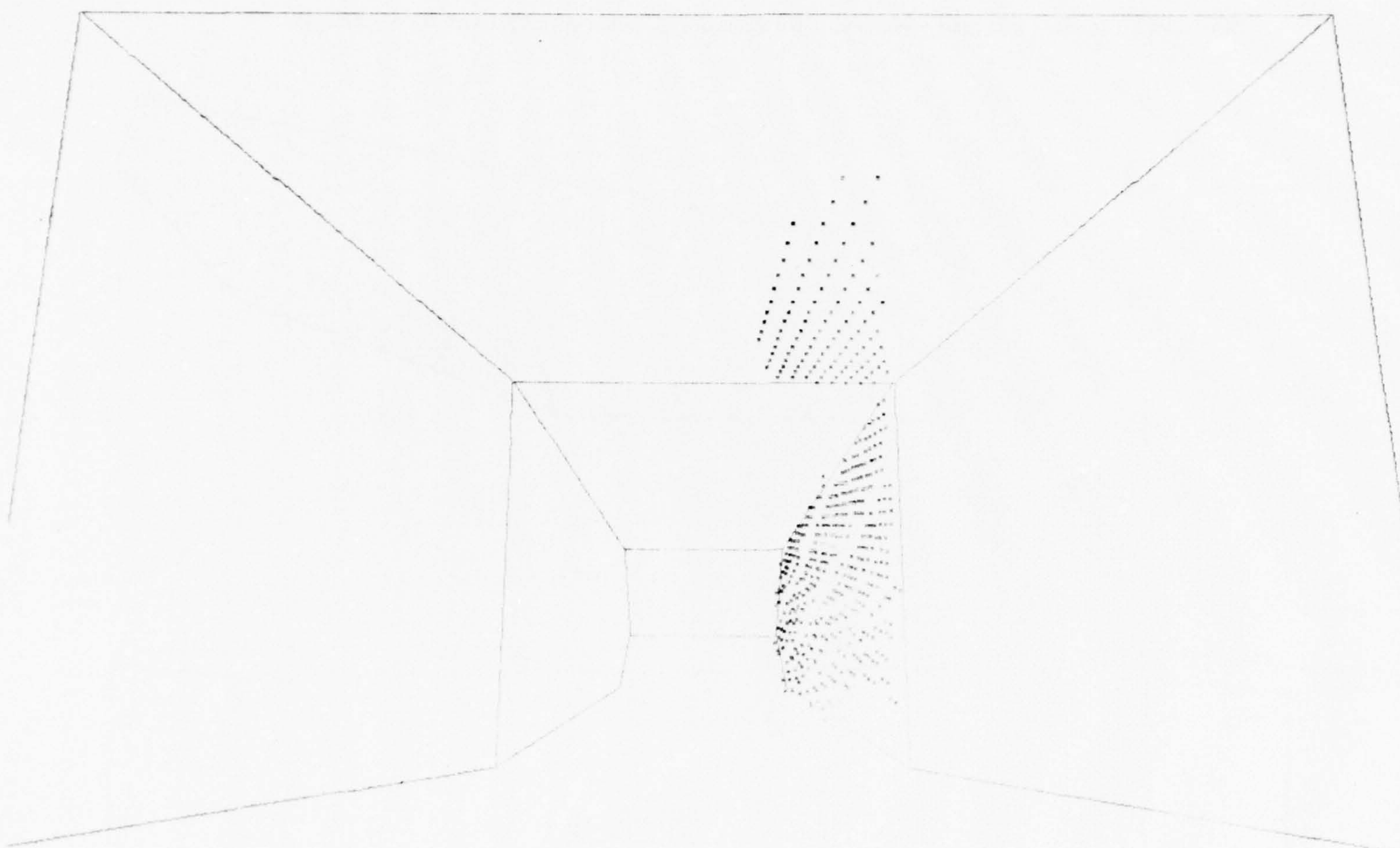

Figure 8A. Perspective reflection points on top surface due to external light rays entering forward side.

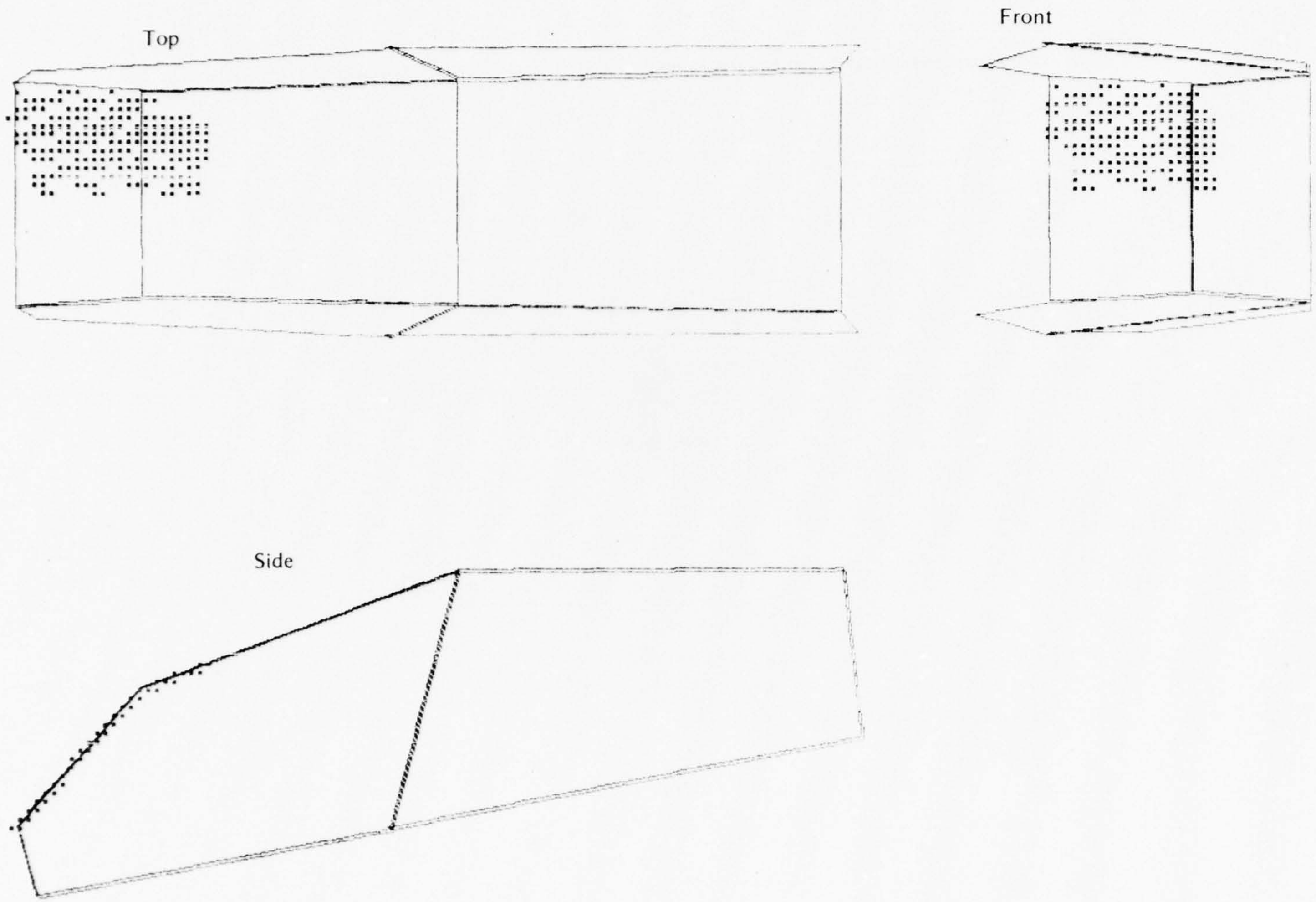

Figure 9A. Primary reflection points on upper frpnt panel due to external light rays entering lower front.

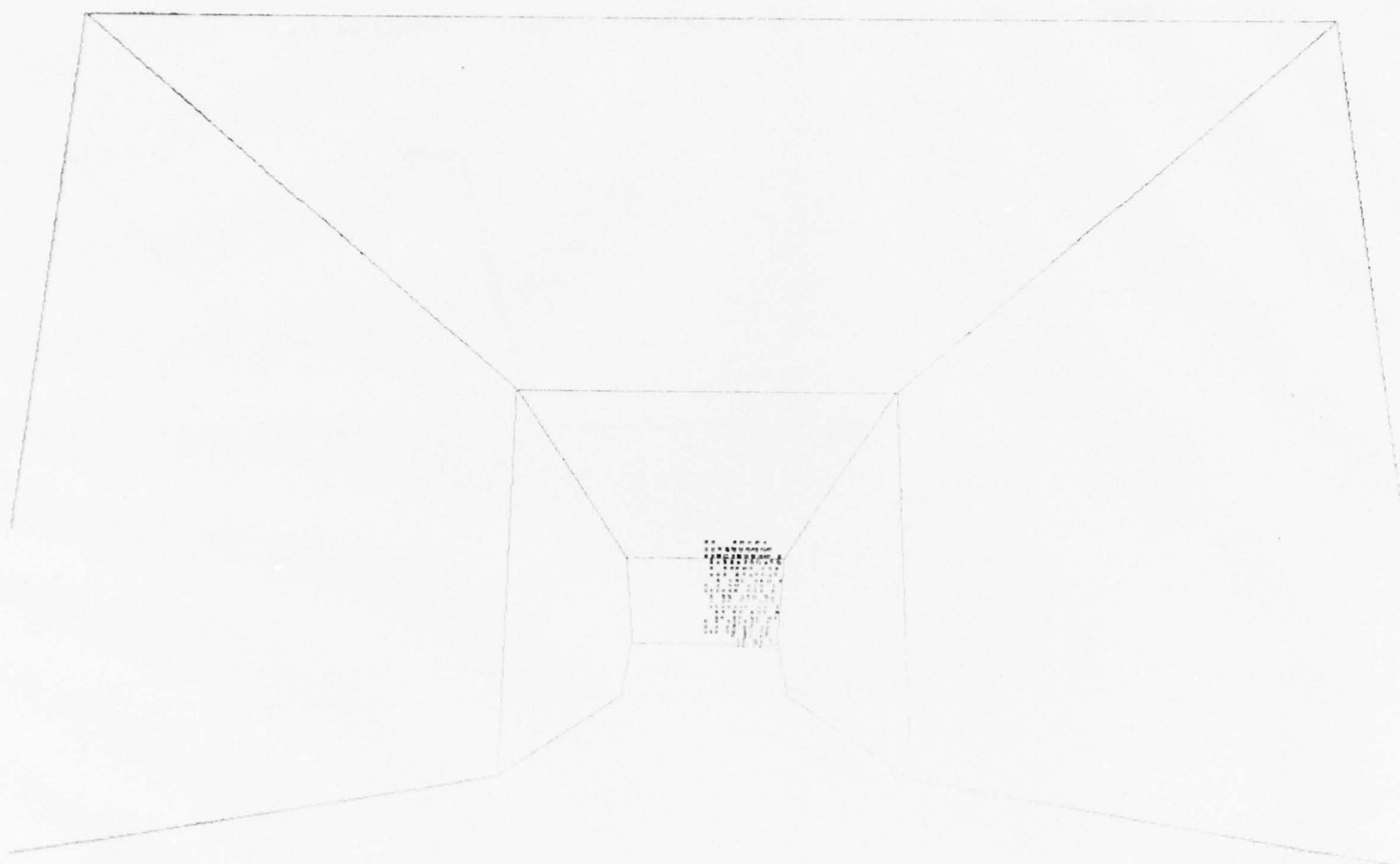

Figure 10A. Perspective reflection points on upper front panel due to external light rays entering lower front.

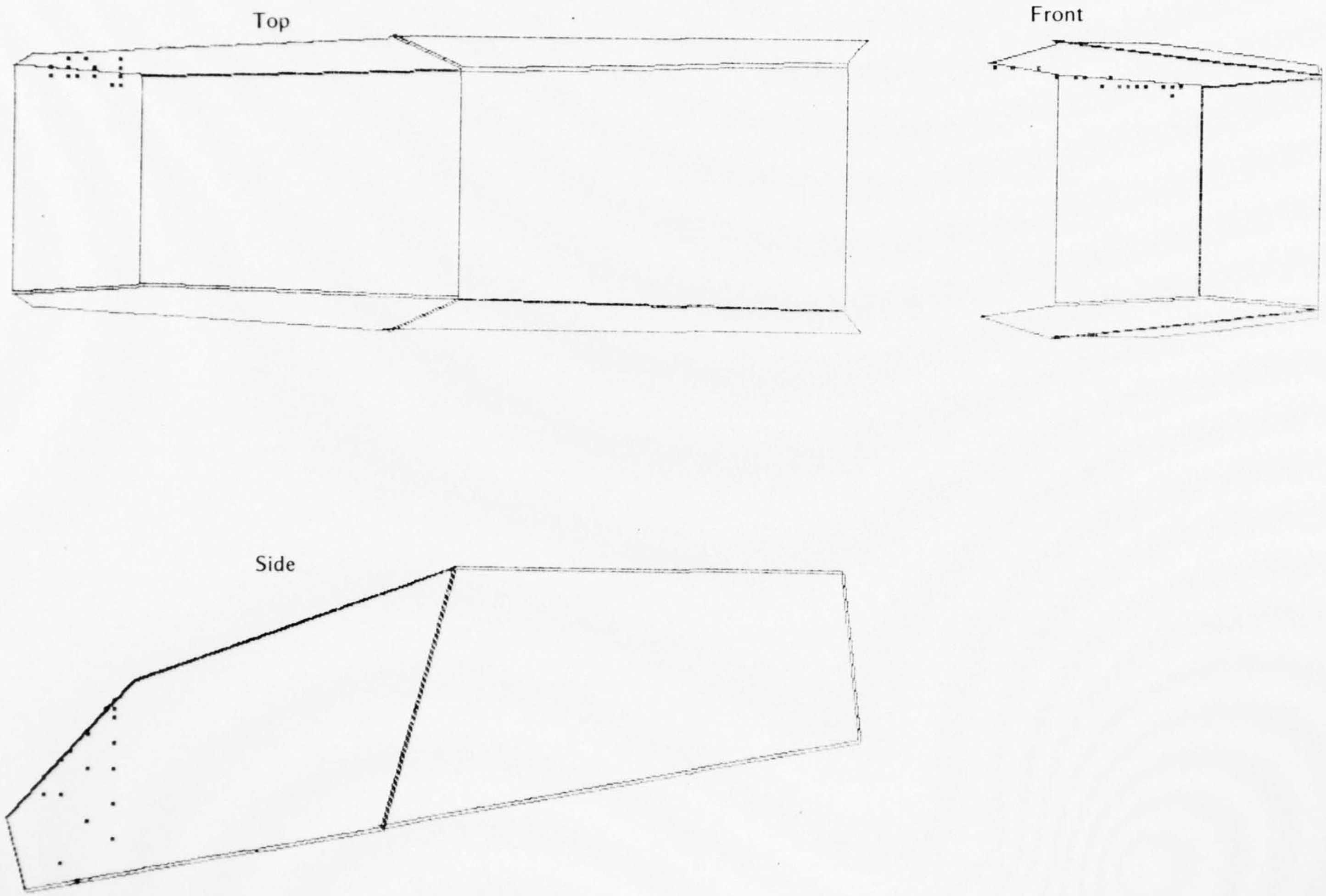

Figure 11A. Primary reflection points on lower front panel due to external light rays entering forward side.

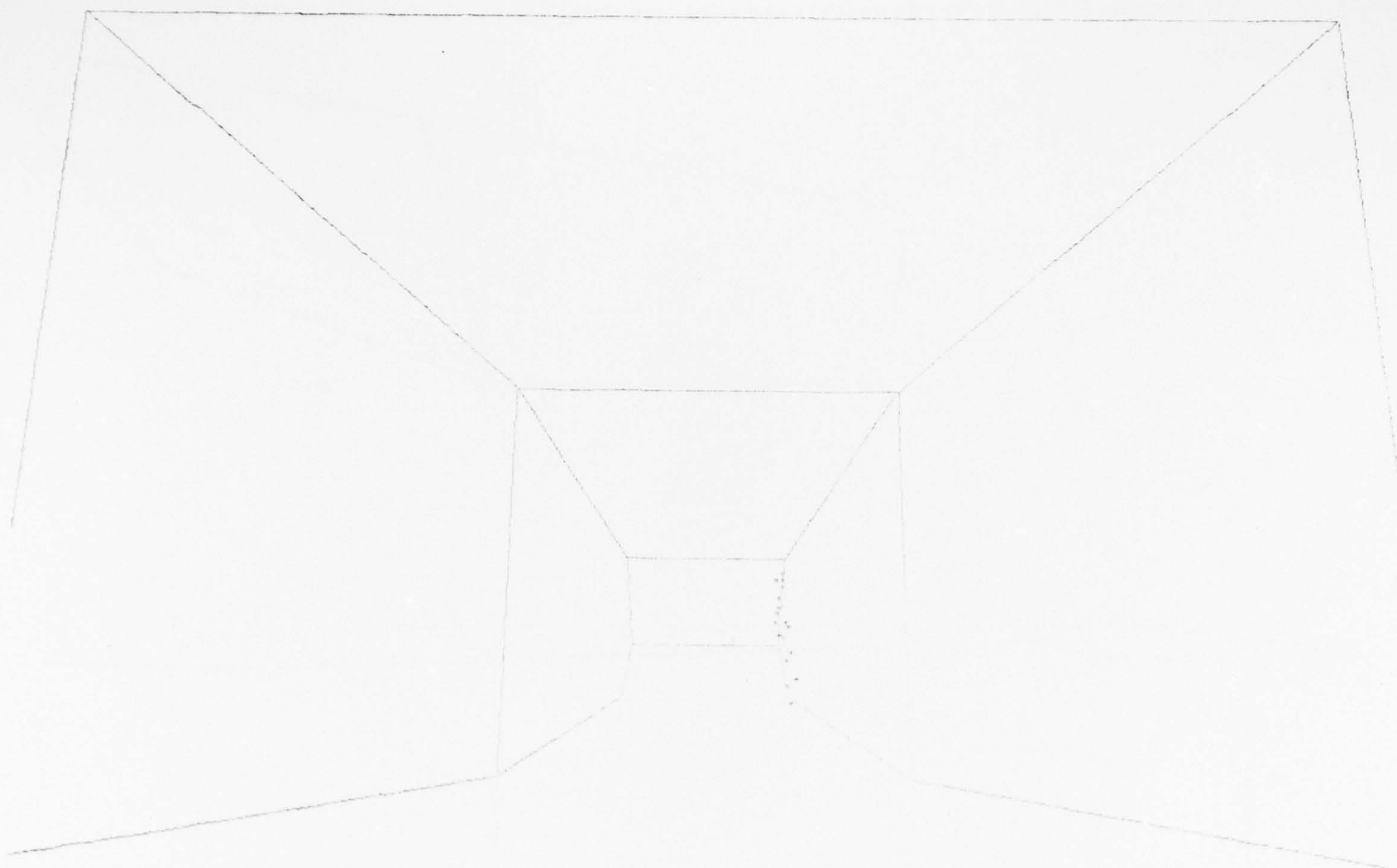

Figure 12A. Perspective reflection points on lower front panel due to external light rays entering forward side.

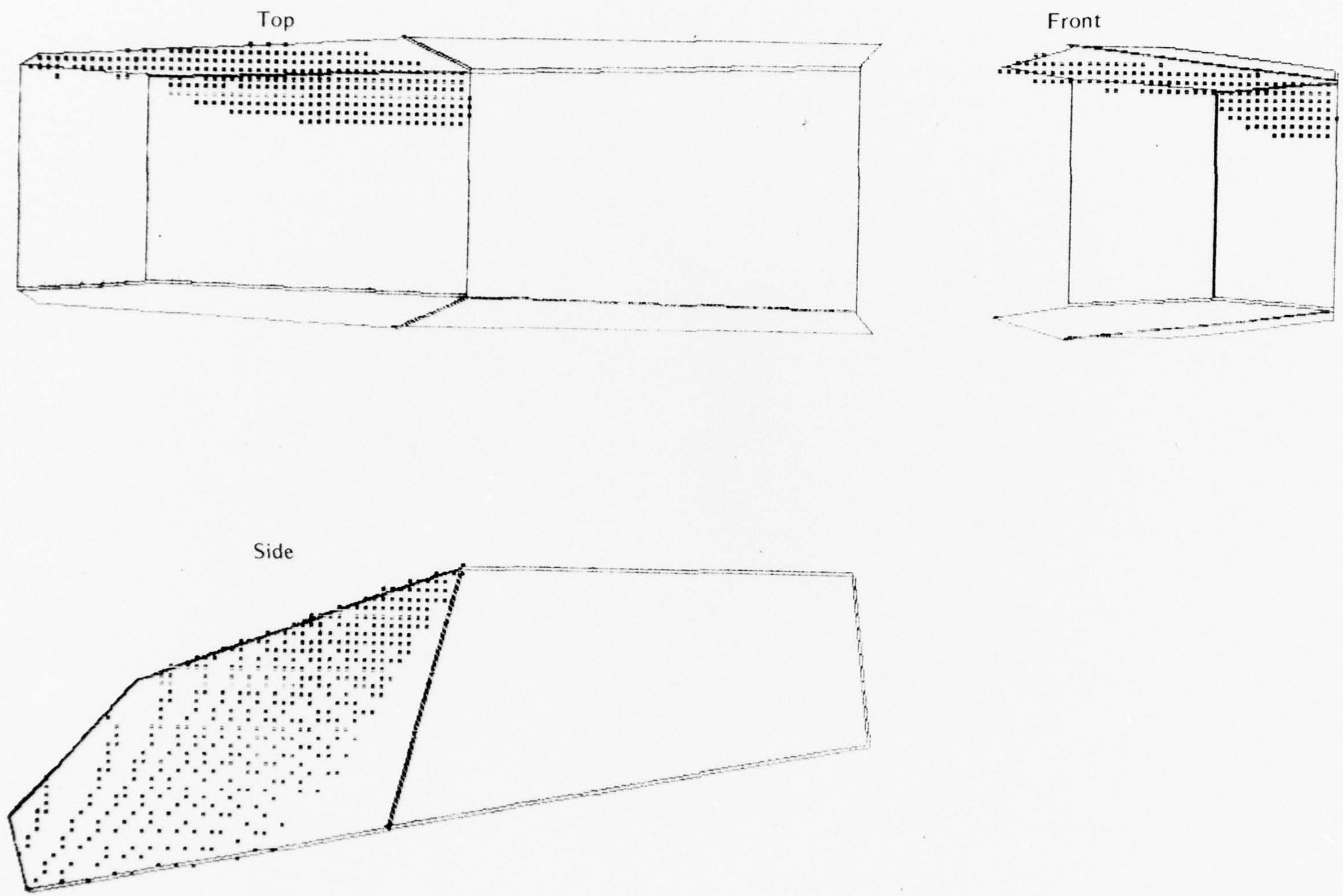

Figure 13A. Primary reflection points on upper front surface due to external light rays entering forward side panel.

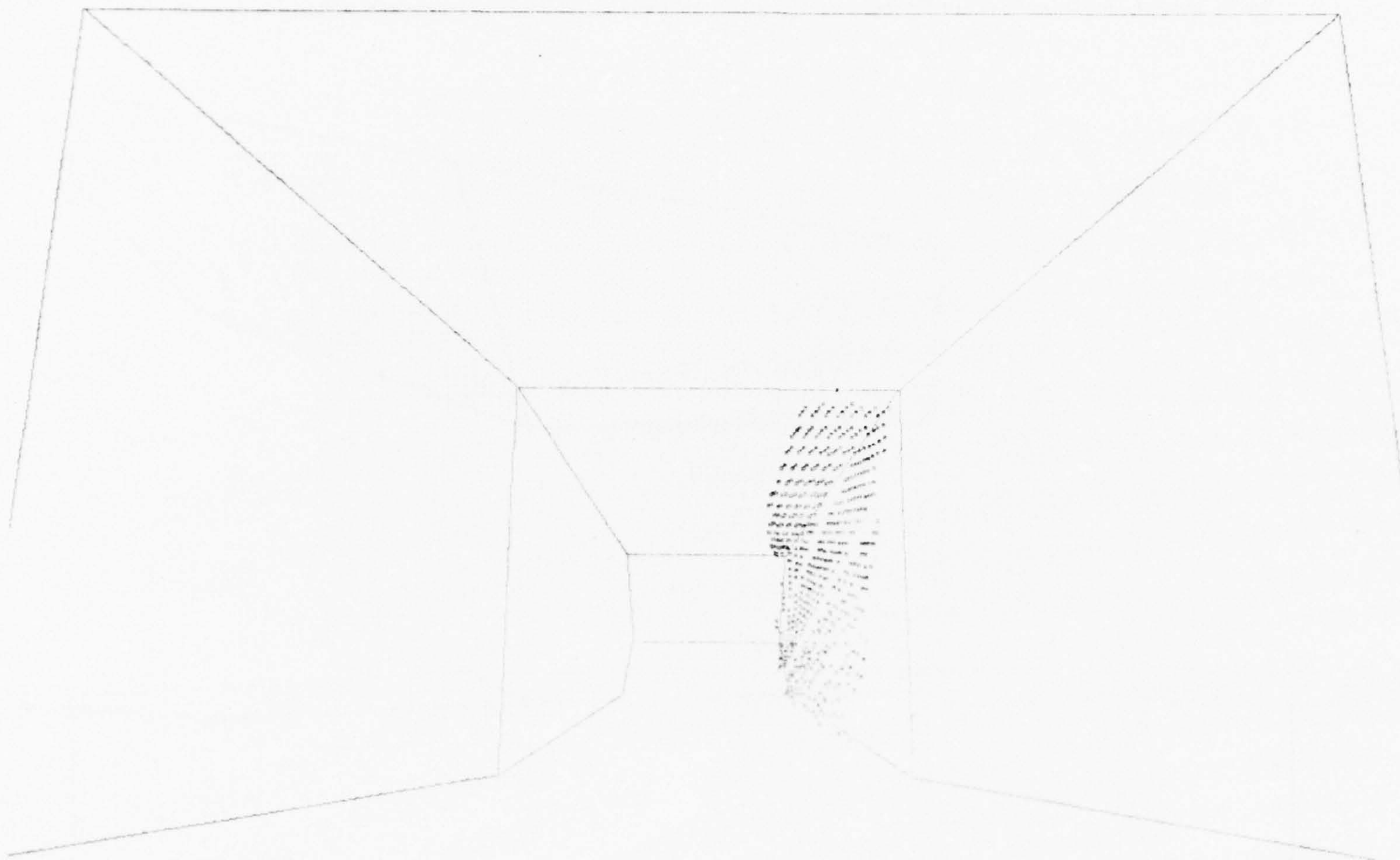

Figure 14A. Perspective reflection points on upper front surface due to external light rays entering forward side panel.

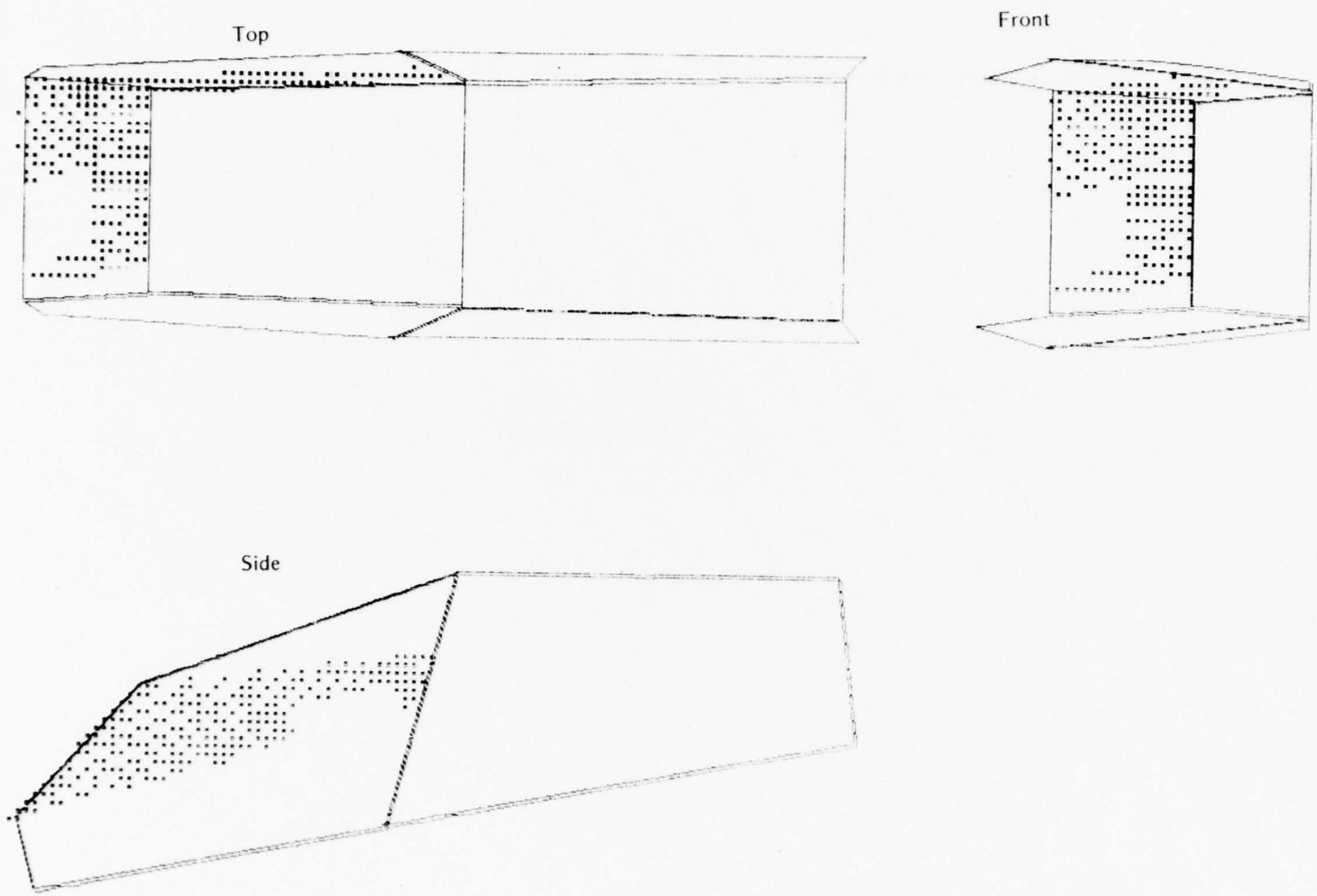

Figure 15A. Primary reflection points on forward side panel due to external light rays entering lower front panel.

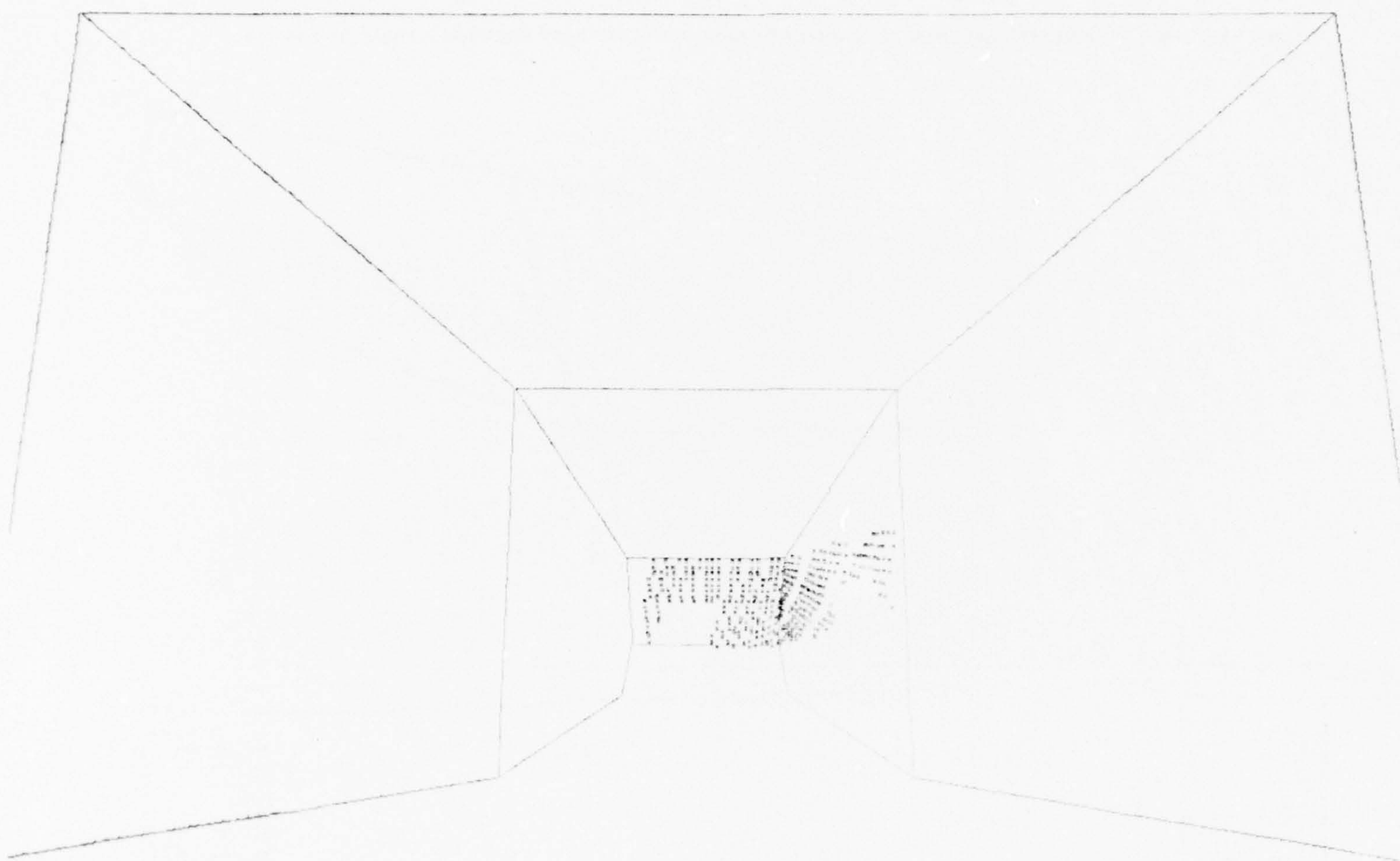

Figure 16A. Perspective reflection points on forward side panel due to external light rays entering lower front panel.

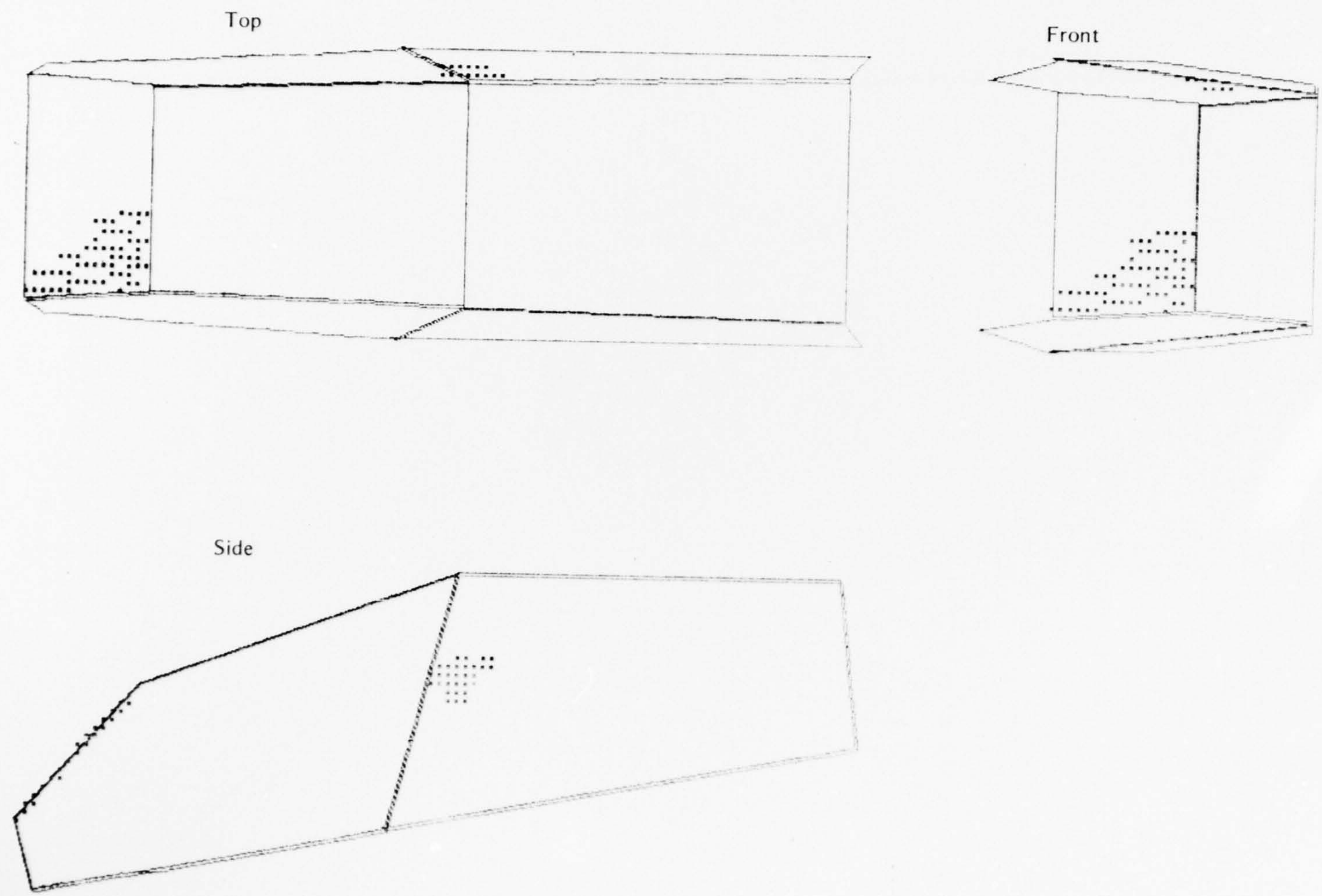

Figure 17A. Primary reflection points on rear side panel due to external light rays entering from lower front panel.

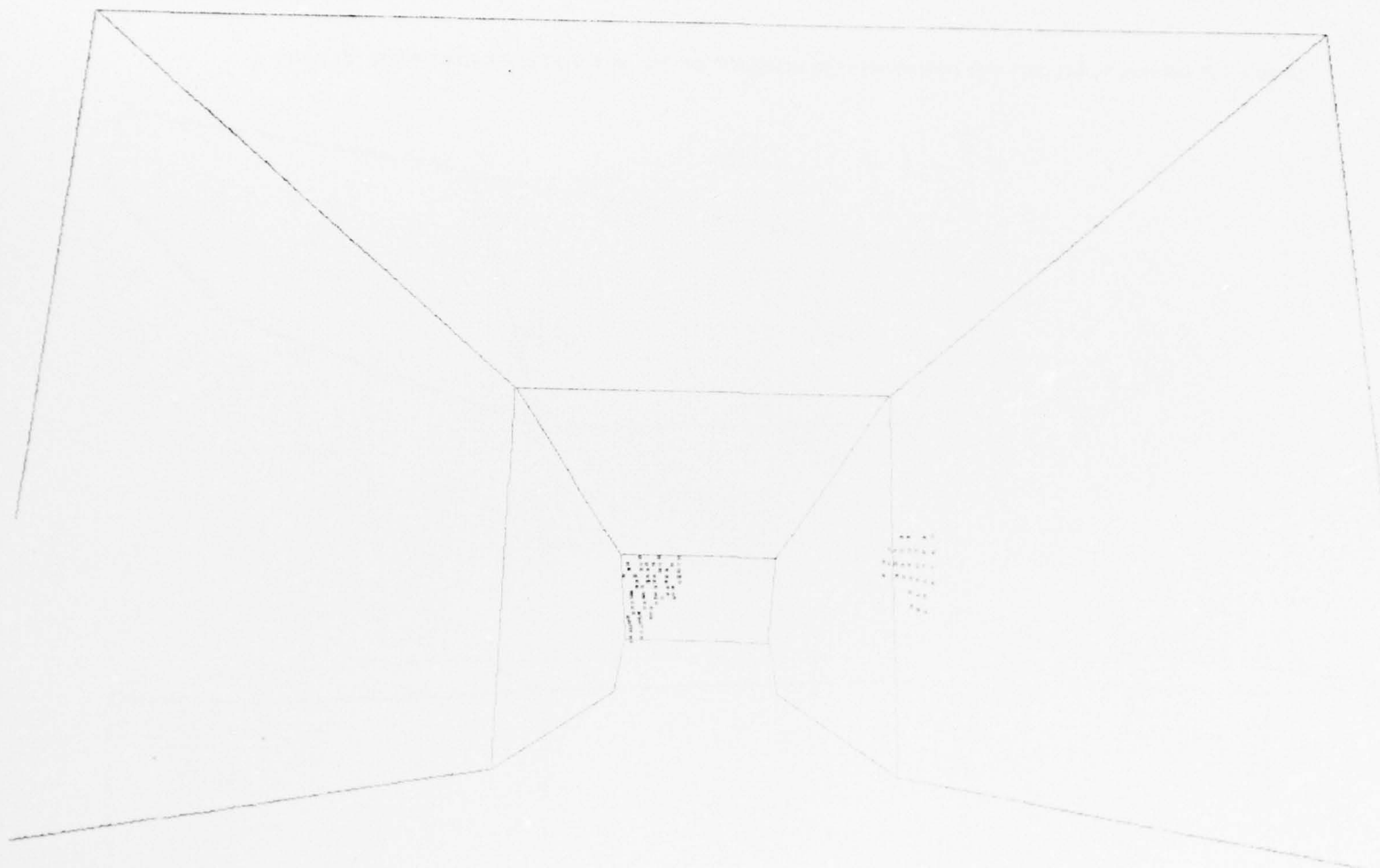

Figure 18A. Perspective reflection points on rear side panel due to external light rays entering from lower front panel.

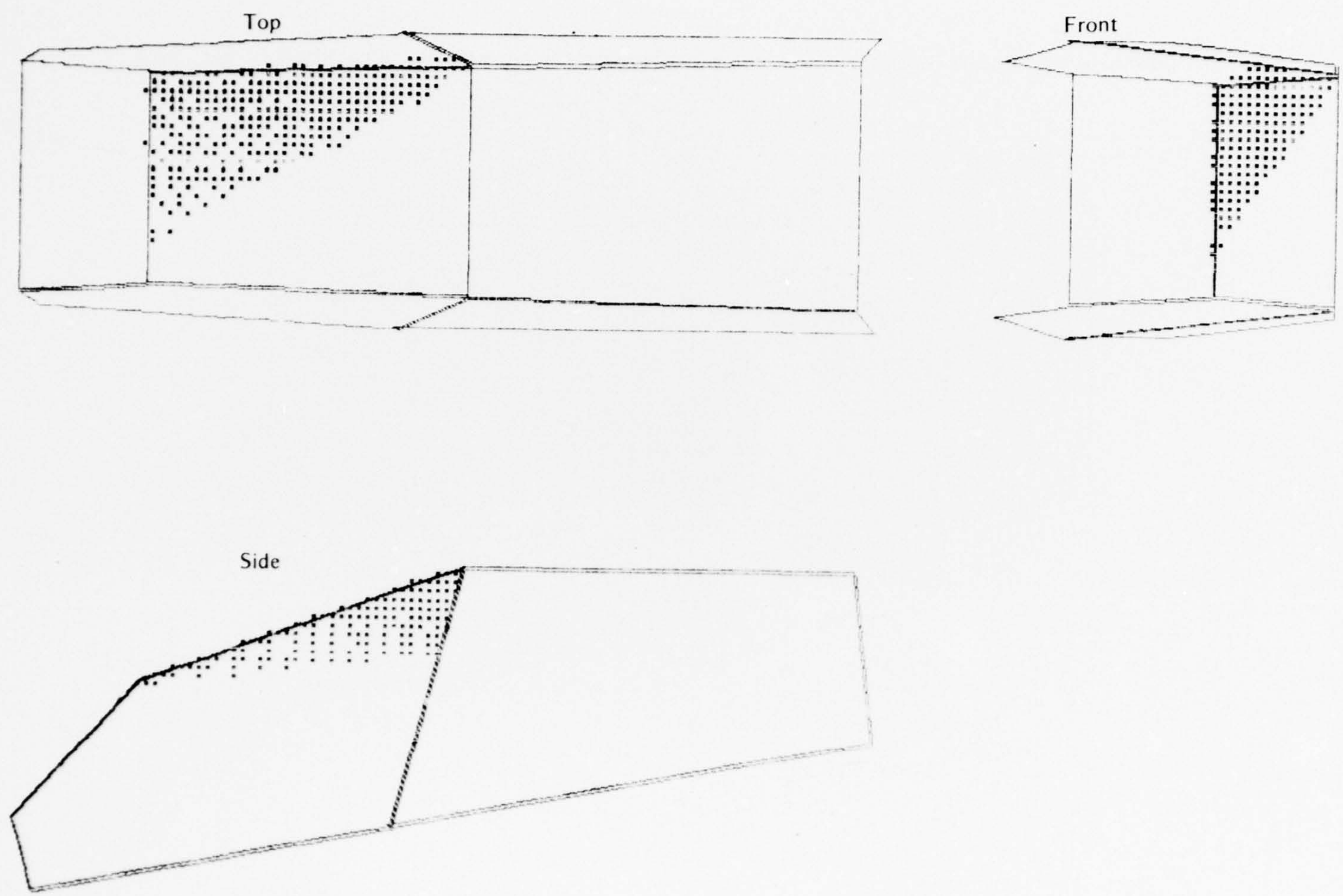

Figure 19A. Primary reflection points on forward side panel due to external light rays entering upper front panel.

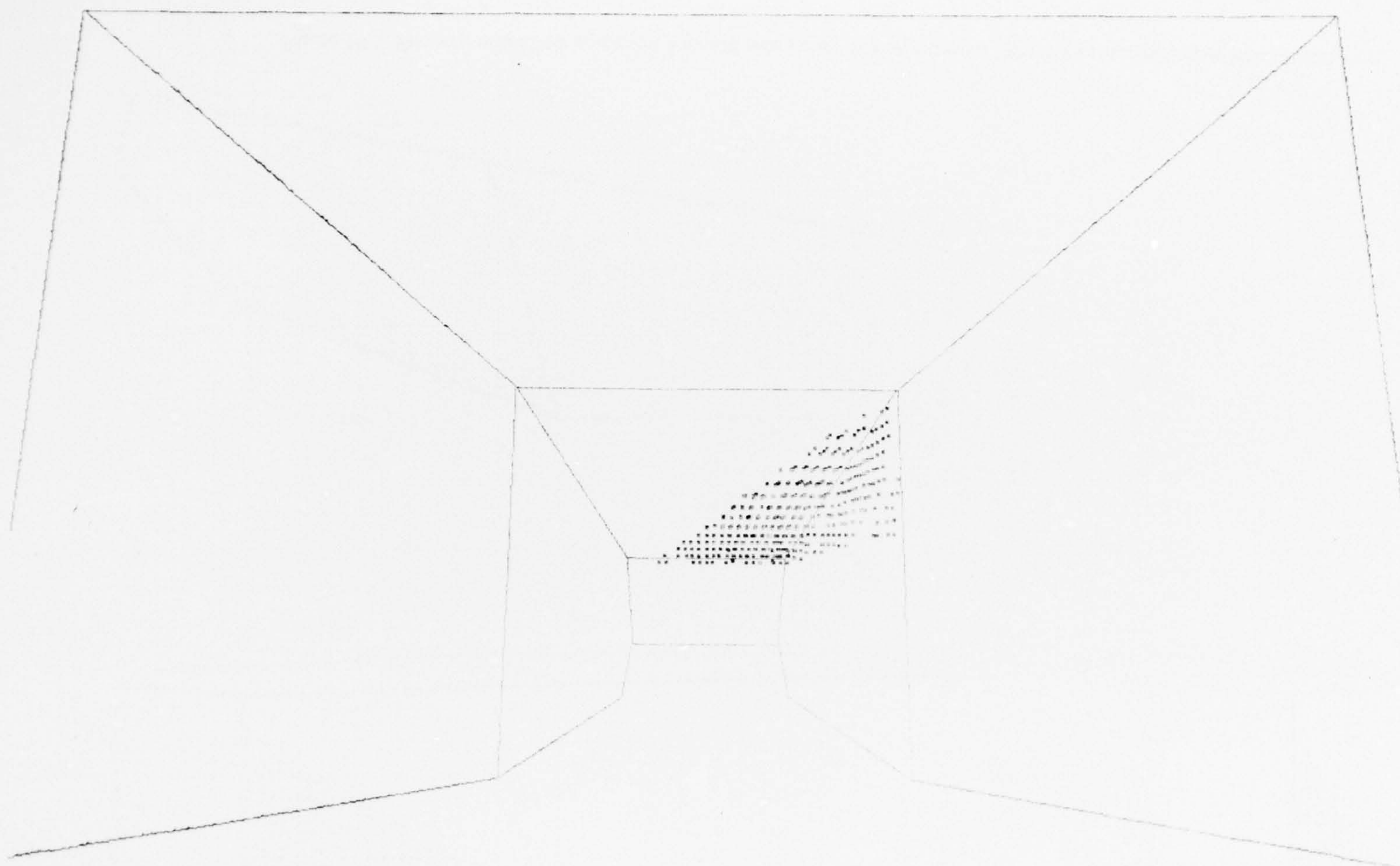

Figure 20A. Perspective reflection points on forward side panel due to external light rays entering upper front panel.

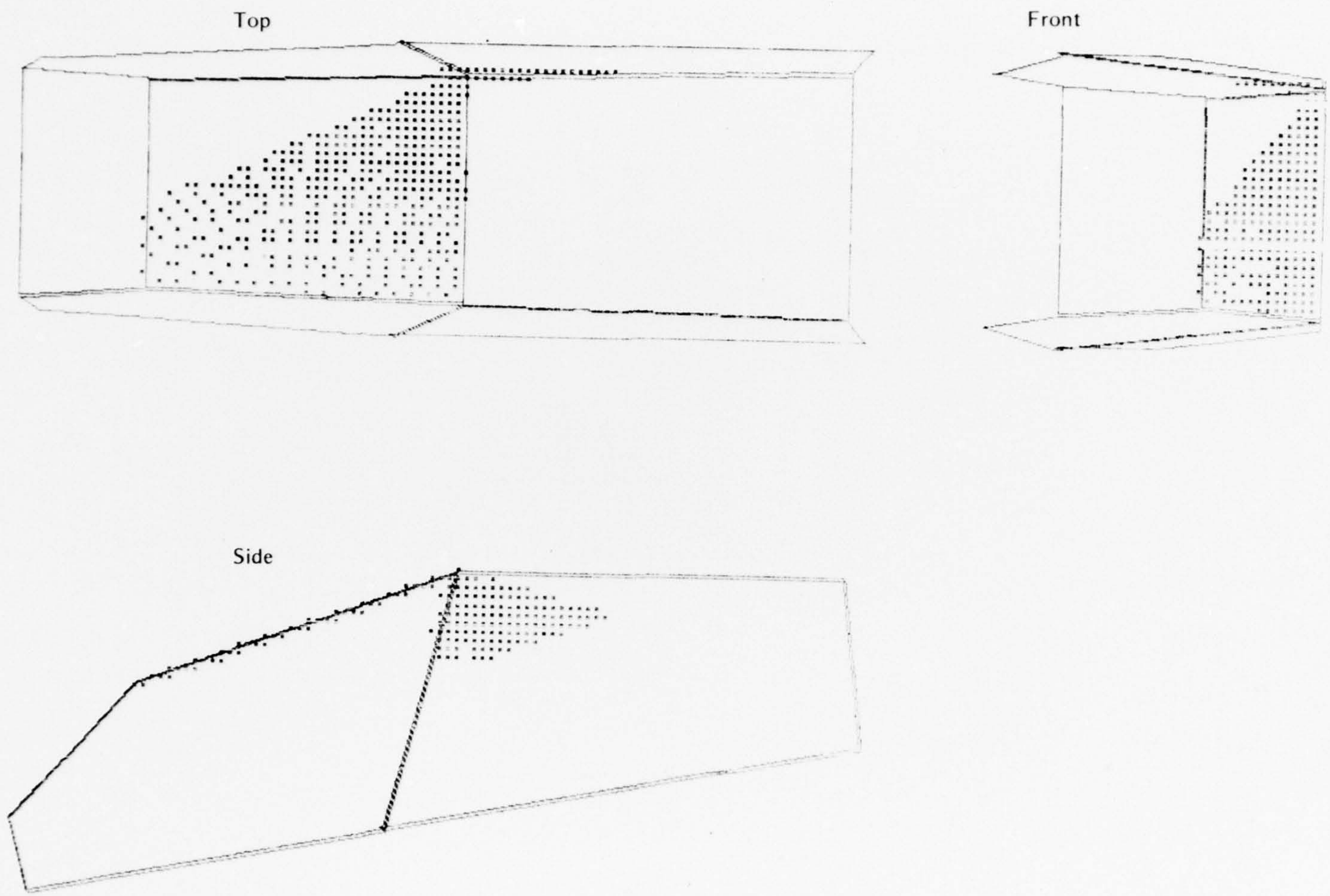

Figure 21A. Primary reflection points on rear side panel due to external light rays entering upper front panel.

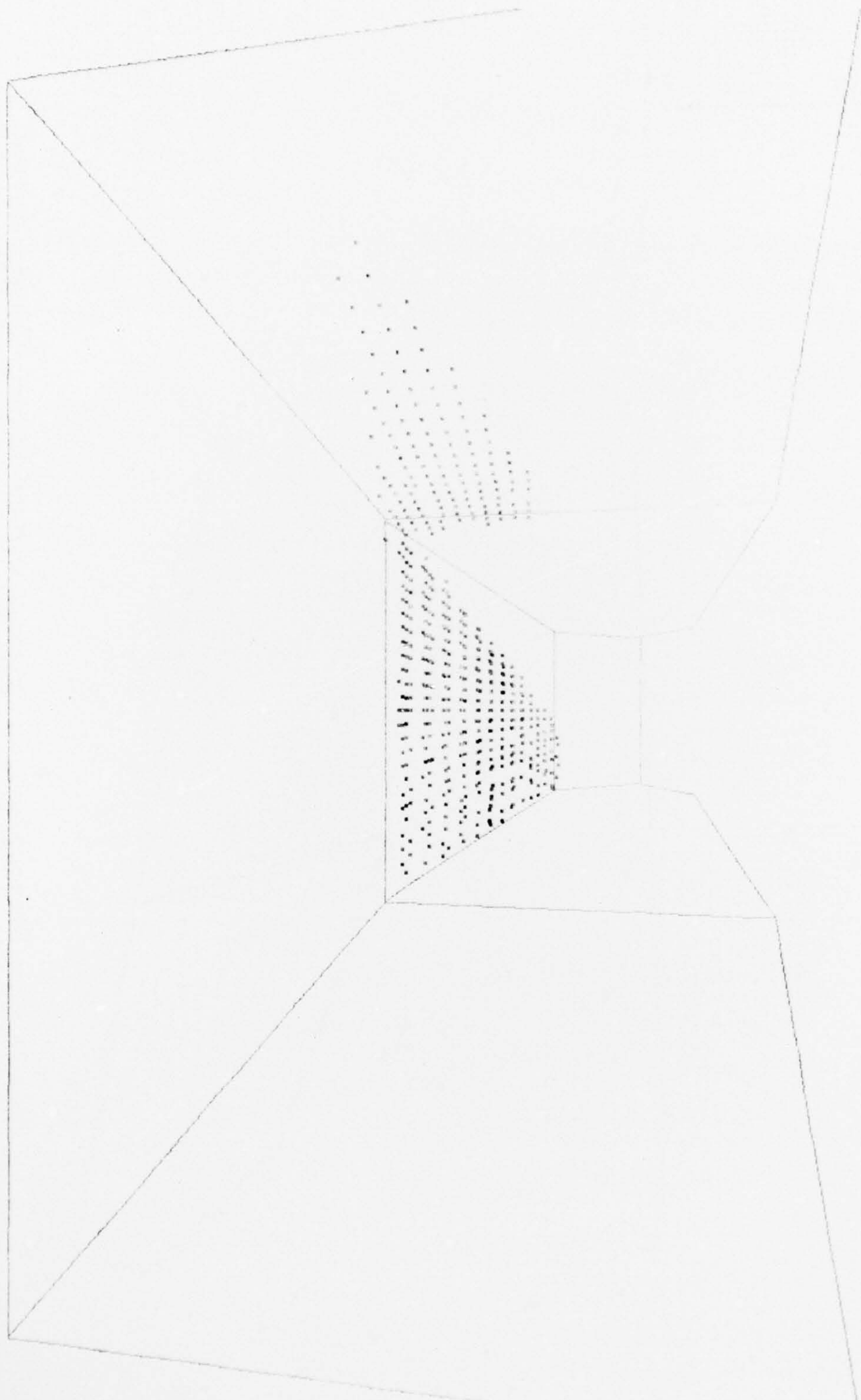

Figure 22A. Perspective reflection points on rear side panel due to external light rays entering upper front panel.

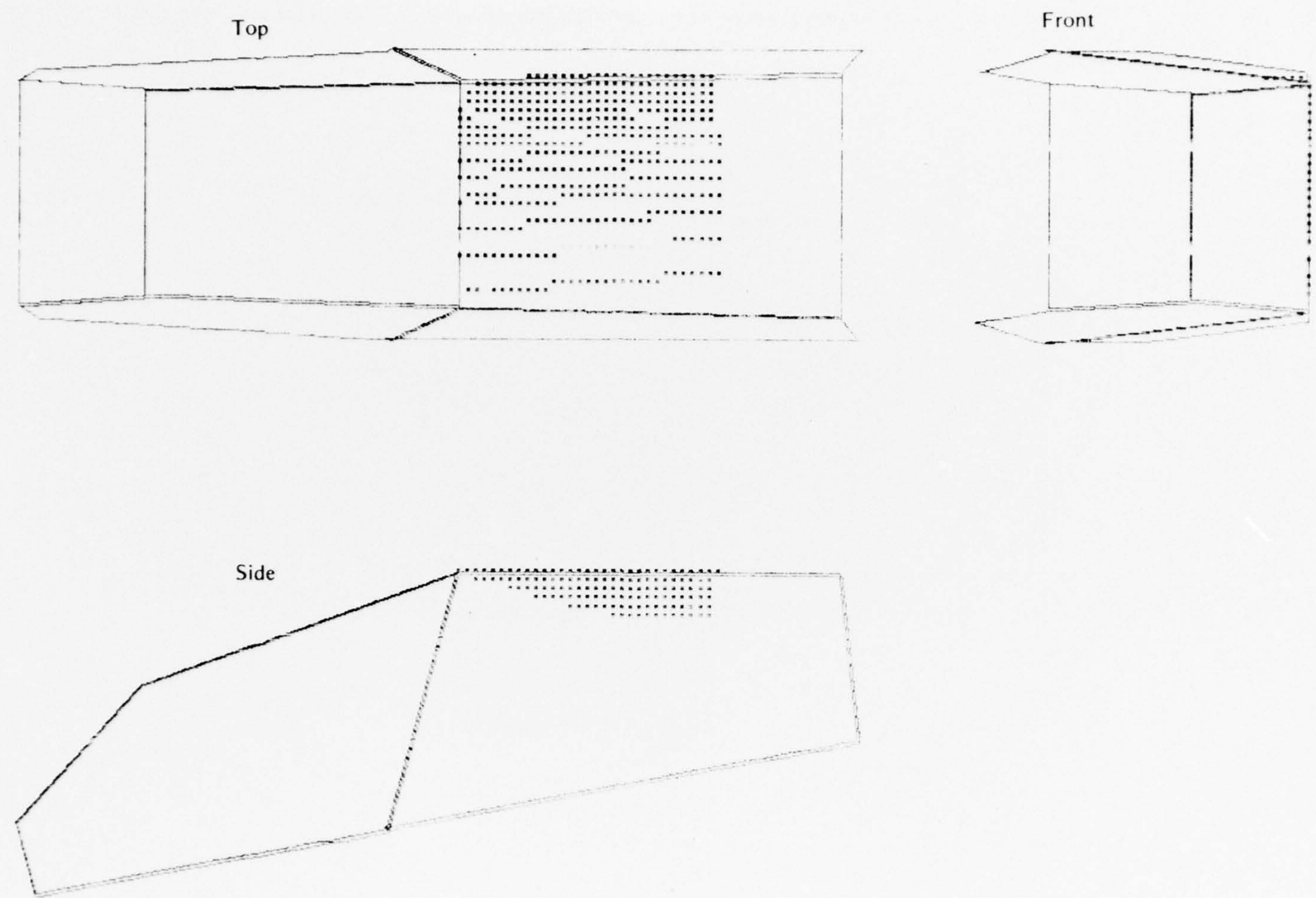

Figure 23A. Primary reflection points on rear side panel due to external light rays entering from top panel.

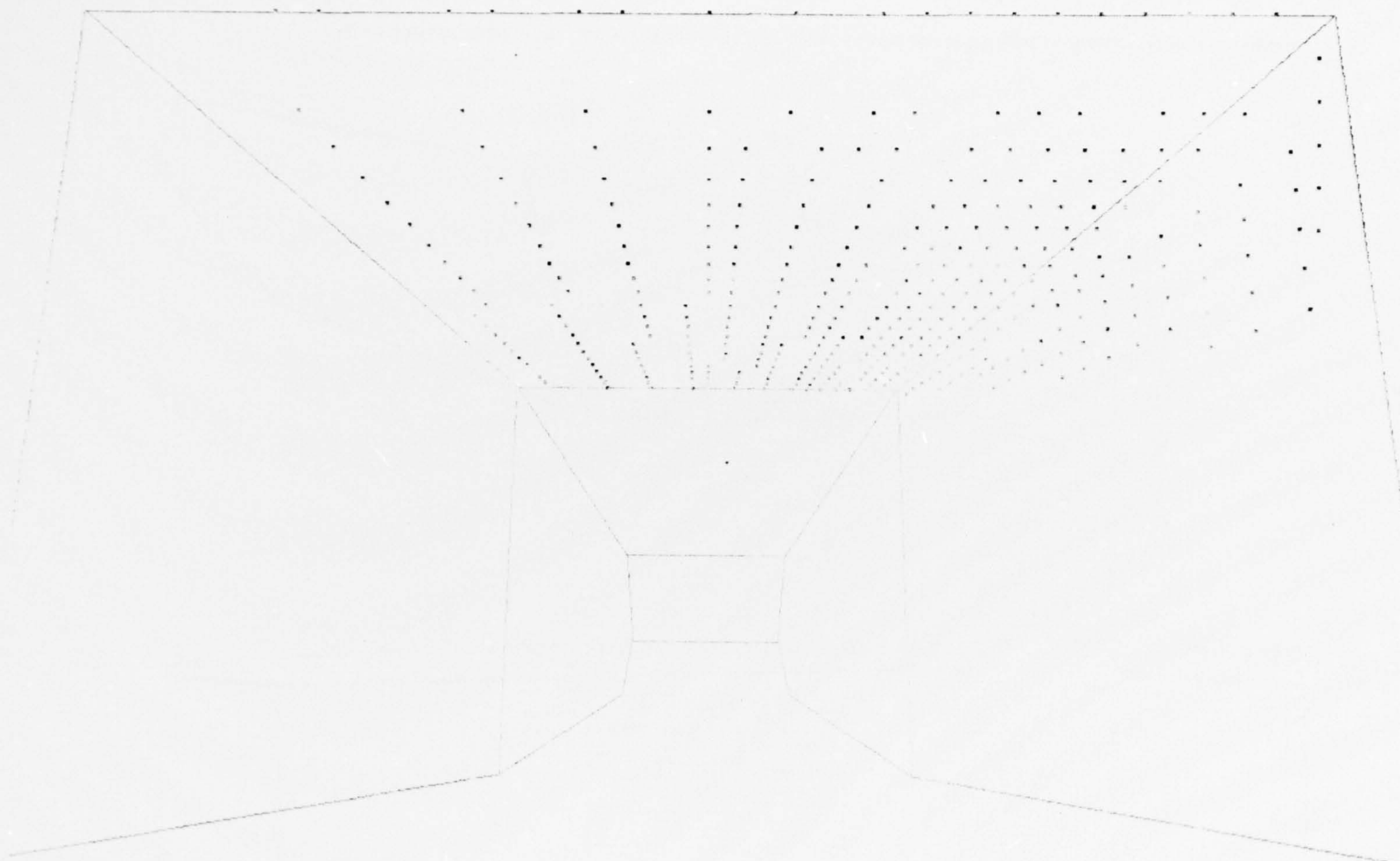

Figure 24A. Perspective reflection points on rear side panel due to external light rays entering from top panel.

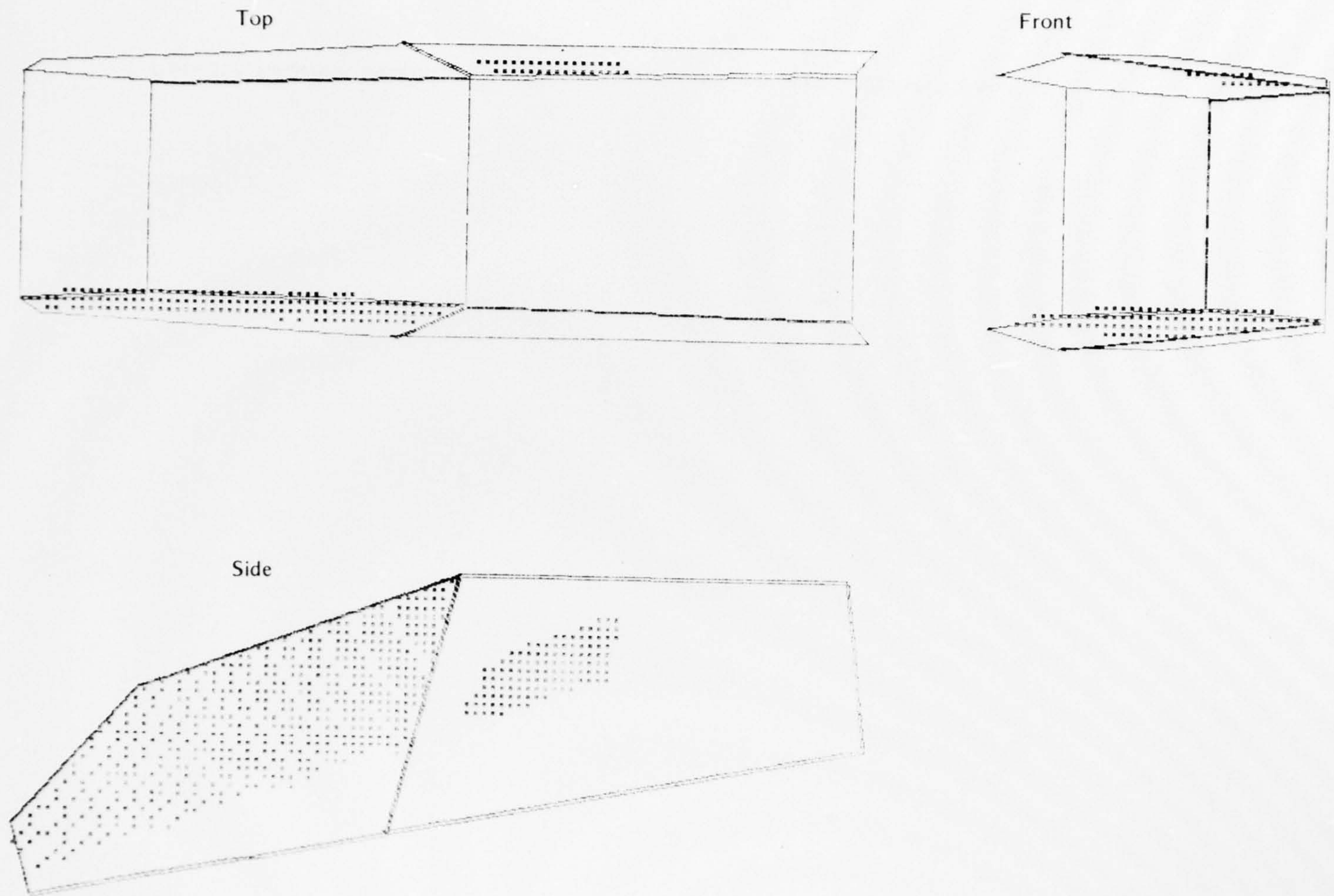

Figure 25A. Primary reflection points on rear side due to external light rays entering front side panel.

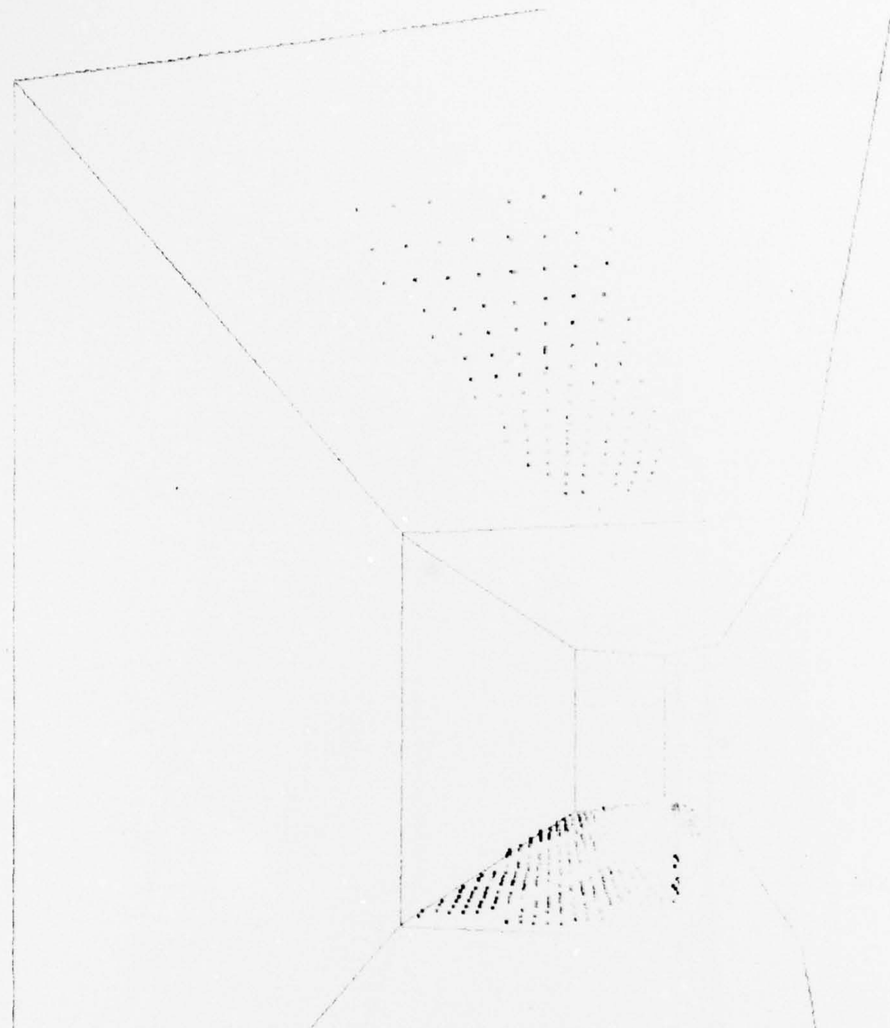

Figure 26A. Perspective reflection points on rear side due to external light rays entering front side panel.

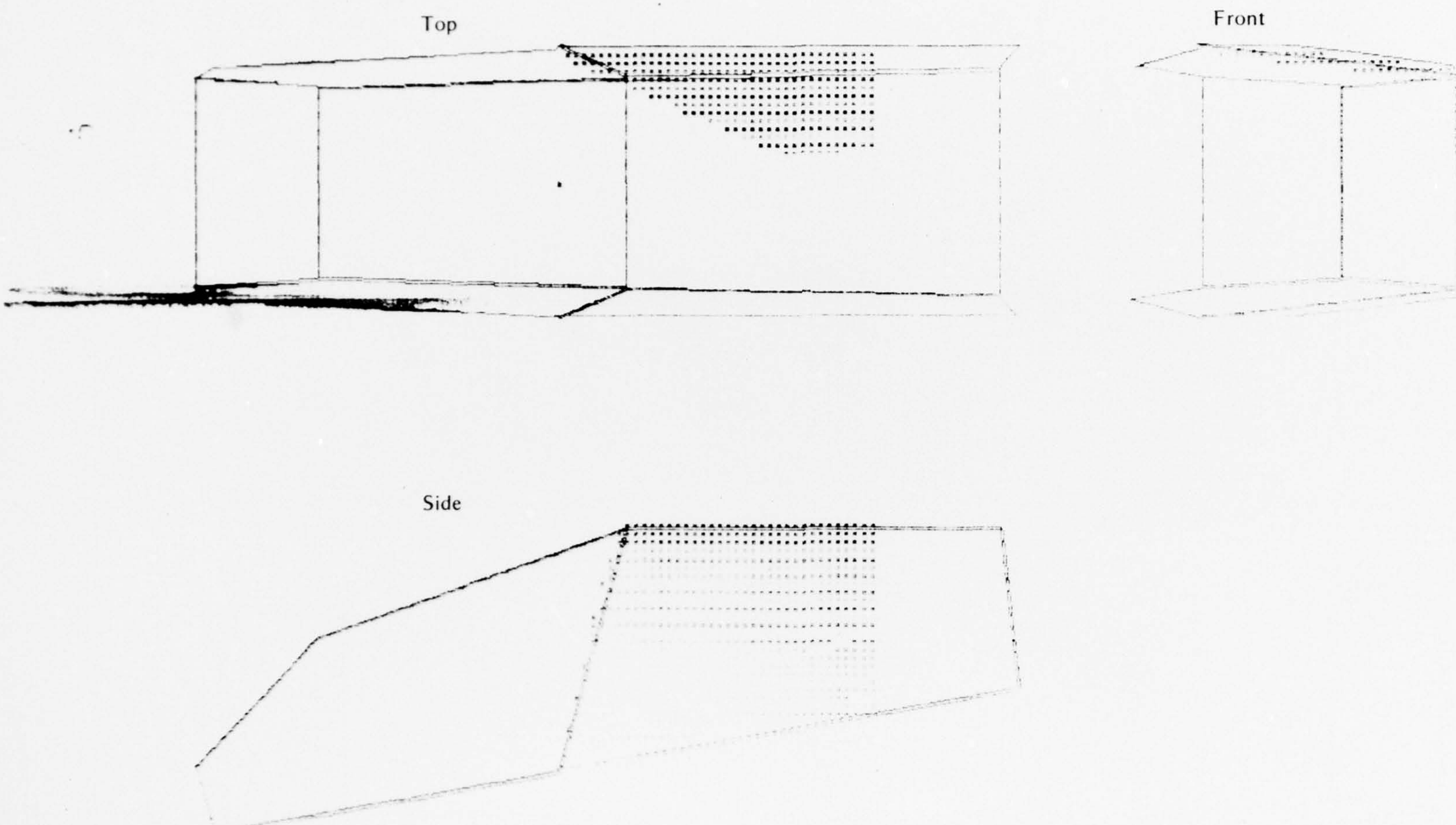

Figure 27A. Primary reflection points on top surface due to external light rays entering rear side panel.

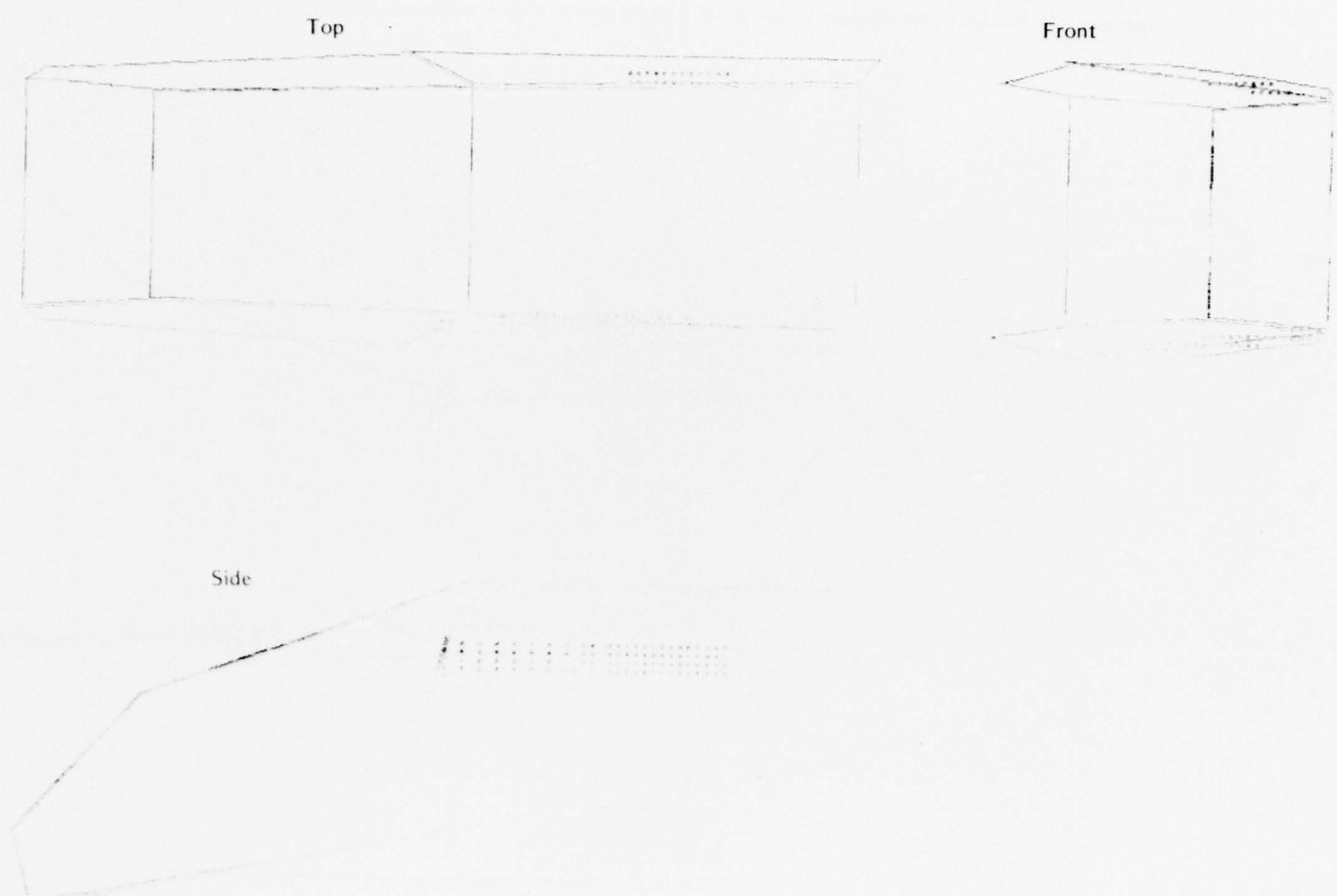

Figure 28A. Primary reflection points on RMS rear side panel due to external light rays entering LMS rear side panel.

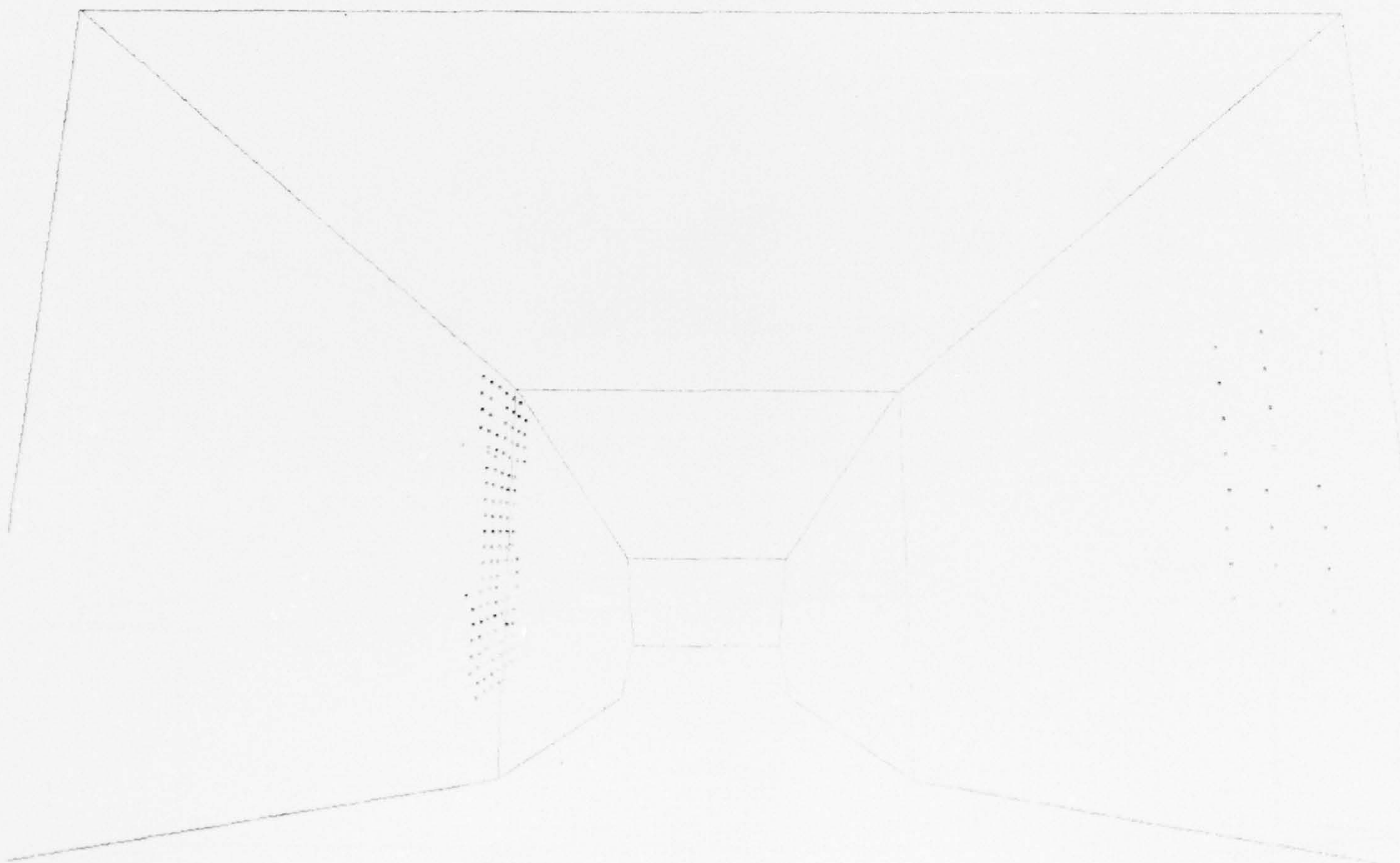

Figure 29A. Perspective reflection points on RHS rear side panel due to external light rays entering LMS rear side panel.

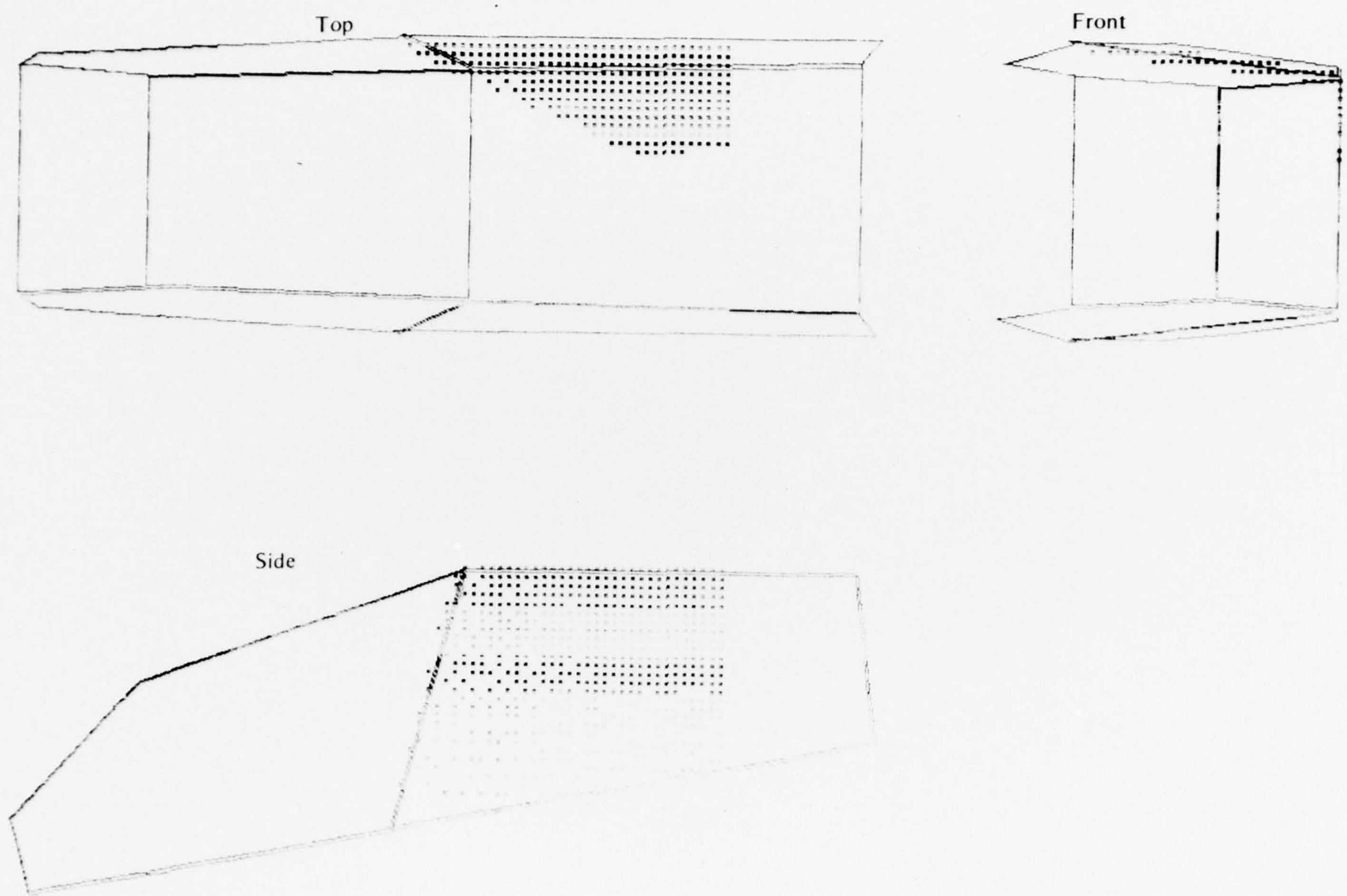

Figure 30A. Primary reflection points on top surface due to external light rays entering from rear side panel.

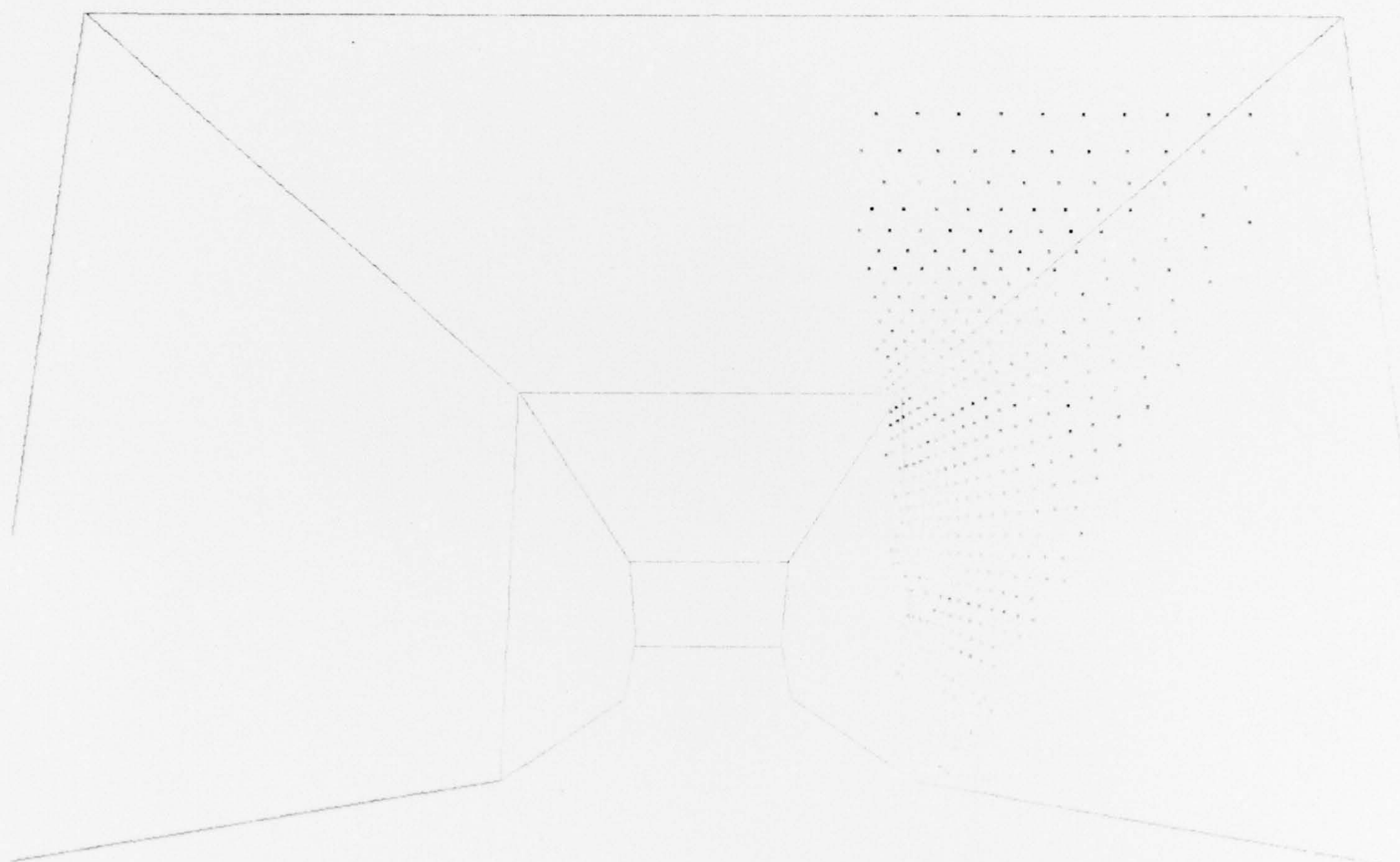

Figure 31A. Perspective reflection points on top surface due to external light rays entering from rear side panel.